Metal PROGRESS

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RESISTORS FOR ELECTRIC HEATING

BY THE EDITOR OF METAL PROGRESS

NOTEWORTHY improvement in the life and operating temperature of electrical resistors has taken place within the last few years, and this statement holds true for the entire range of such materials from those suitable for cooking or baking to those for forging furnaces and kilns for firing ceramics.

For instance, open-coiled resistors placed in a tile for a heating element in electric ranges a decade since would burn out within two or three years. Improvements aimed at something which could be embedded and protected in a flat-top plate, have the life of the range itself and glow hot enough to boil water speedily.

"Calrod" is one example; it comprises a long helix of resistor wire contained in a thin metal tube packed with magnesia. In these the tubular sheath has been the critical factor. Plain steel, steel with an aluminized surface, high chromium-nickel steels, and "Inconel" (79-13-8 Ni-Cr-Fe) represent successive improvements. The latter, although the most expensive, is free from excessive grain growth and carbide decomposition to which the others eventually succumb.

While cast grids of the type 60% nickel, 12% chromium are now used extensively in large heat treating furnaces, the 80% nickel, 20% chromium analysis ("Nichrome" or "Chromel") continues to be the standard resistor wire and heating element for heaters and furnaces where space is limited. Patented by A. L. Marsh in 1906, it forms the basis of the appliance industry. Since that time intensive study has endeavored to improve its qualities, and the article by Mr. Bash on page 143 indicates that this has been achieved without diverging from the optimum analysis, but by a perfected melting, deoxidation and processing routine. Ten years ago an accelerated test for determining the life of fine wire was adopted by the American Society for Testing Materials, and a test temperature of 1950° F. adopted. Today the test temperature must be 200° higher to increase the resistance of the wire by 10% within a reasonable time, say 100 to 150 hr.

This means longer and longer life at moderate temperatures, or economical service at higher and higher temperatures. Ten years ago the safe maximum operation of a resistor furnace was about 1850° F.; now 2100° F. may be reached with heavy heating elements and well designed supports and even 2200° F. where blanketed with hydrogen atmospheres. The importance of design and installation must be emphasized. Resistors may fail by the development of "hot spots," and these usually are at places where free radiation of heat is prevented, by gradual oxidation at the surface or, in finer wires, by hot spots developing at imperfections on the surface or oxide inclusions.

"Tubulaire," a vertical tubular element, is most interesting. Ribbons of 80-20 nickel-chromium alloy, welded in the form of straight tubes, are mounted vertically as resistors and with unobstructed ends so that a chimney effect insures uniform temperature, end to end, and also transfers heat to the work by the mild convection currents so induced in the furnace atmosphere. Both factors should tend toward increasing the effective range of the furnace.

While 2100° F. represents an operation undreamed of 20 years ago with metallic elements, this does not reach some modern

demands, as for forging, the heat treatment of high speed steel, and the firing of many ceramic products. Some of these clearly exceed the capacity of the nickel-chromium resistor for they approach its melting range, but are easily reached by non-metallic resistors of the silicon carbide type, and these too have been improved. But mention should first be made of relatively new metallic resistors for extra high temperature ranges.

Earliest in commercial development is the Swedish alloy "Kanthal" (approximately 25% chromium, 5% aluminum, 3% cobalt, balance iron). Originally developed to save on expensive alloying elements, it has proved suitable for higher operating temperatures than 80% nickel, 20% chromium. European practice is cited by the manufacturers to show that the elements, depending on grade and analysis, can operate satisfactorily from 2100° F. to 2150° F. — as for instance, two years in a ceramic kiln at 2200° F. The alloys have low creep strength, so wavy ribbons are placed on edge in slots in the brick walls.

Two years ago "Smith Alloy No. 10" was announced by Dr. Hoyt (Metal Progress, July 1935). Its type analysis is 37.5% chromium, 7.5% aluminum, balance iron, "a composition giving extraordinary stability at high temperatures and high fusion point." Although it is brittle at room temperatures, it has good hot working properties, where it can be forged, pressed or drawn. Life tests are analogous to the A.S.T.M. standard except that the test temperature is 2600° F. to give results in 100 hr. Commercial developments are now in the hands of firms specializing in furnace construction and resistor manufacture, and it is confidently believed that units with an economical operating life at 2400° F. will be possible. Obviously this is getting to a point where the supporting refractories must be of special and highest quality. It is also to be hoped that they will not deteriorate in the "controlled atmospheres" now so interesting to heat treaters.

Mention might also be made of a resistor recently tested at Carnegie Institute of Technology. It comprises a rod of molybdenum metal thinly coated with a fusible glass and the whole contained in a sillimanite tube. It was operated at 2900° F. for considerable time without observable change. Whether the promises of these laboratory tests will be borne out in working installations remains to be seen; even if volatilization and oxidation of the metal are effectively prevented, sillimanite tubes are very fragile, as pyrometer users can all testify.

Such exceedingly high temperatures have for many years been successfully delivered by rods of selected silicon carbide known as "Globar." Improved construction, exhibited at the last National Metal Congress, eliminates large thermal losses through water-cooled electrical connectors in the following manner: That portion of the element which is exposed inside the furnace is made of silicon carbide having a high electrical resistivity; both ends, however, merge into a mixture of much lower resistivity and thermal conductivity. These "pin ends," smaller in diameter, butt against terminal rods of similar composition, long enough to pass through the furnace walls and insulation, and at the outer end meet a polished aluminum terminal, the whole combination being held together in good contact by spring devices. The result is a terminal, without water cooling, that never gets hot enough even to oxidize, despite a temperature up to 2500° F. at the resistor inside the furnace chamber.

A high temperature furnace consisting merely of a tubular "Globar" is obviously possible, and such have operated continuously at temperatures up to 2850° F. So far the size is limited to 2 in. inside diameter. Such a tube, 36 in. long, in a well-insulated refractory case and with water-cooled end connectors, will have a central length of 16 in. at substantially uniform temperature when operating at 2800° F.

BIA-EN-PET

In an article on meteorites in *The Carnegie Magazine* Prof. Robert F. Mehl writes that the Egyptians knew about them, for their ancient word for iron was "bia-en-pet," meaning "marvel from heaven." For a long time, further knowledge on this subject accumulated not at all, judging by a quotation from the books of one Tollius who in 1649 wrote something which may be translated thus: "Meteorites are generated in the sky by a fulgurous exhalation englobed in a cloud by the circumposed humor."

This sounds like Amos and Andy broadcasting in 1938, but an exposition of the modern theories of the structure of matter is scarcely more intelligible to any but the specialist. Others can still conclude that the naive Egyptian came as near to the fundamentals as we can. *He* knew about the nature and origin of iron. It was bia-en-pet, a marvel from heaven.

Mr. Forbes sketches rather broadly some recent trends in foundry practice — particularly of a metallurgical nature having to do with modifications in melting, alloying and heat treating — climaxed with an account of conditions and experiments leading up to the discovery that white iron billets can be rolled into plates, bars and shapes. With proper control of analysis, heat and rolling program, nearly all the necessary graphitization occurs during working, and the end is a metal with a tough fracture much like good wrought iron

NEW CAST IRONS

HEAT TREATED, ROLLED

BY DUNCAN P. FORBES, GUNITE FOUNDRIES CORP.
President Rockford, Ill.

ROLLING of white cast iron into thin plates will strike many persons as a bizarre if not impossible operation. Heat treatment of gray cast iron to improve its strength and toughness will also seem impracticable to others. Refining during melting and the use of alloys will be regarded as semi-commercial operations, warranted now and then by unusual circumstances.

Nevertheless, these very practices as well as analogous ones are in daily use in several progressive American foundries. Cast iron, far from being a single material, made by traditional methods, with certain inferior engineering properties, is a whole series of metallic alloys whose properties are controllable within rather wide limits. Today the term "cast iron" in reality covers a broad field of associated metals, just as the term "steel" covers a variety of generically similar materials.

The subject of cast iron is consequently too large to be considered adequately in a single paper, or, in fact, in a single volume. Cast iron is actually such a complex material that the number of forms the alloy can take is almost unlimited. It is, therefore, my purpose to discuss only some of the more recent developments along the frontier of cast iron metallurgy with which I happen to be familiar. These developments are interesting both to the engineer and metallurgist and are, apparently, not widely known. Also, I shall try to confine myself to developments which appear to have practical value, rather than to developments of a purely scientific nature. At the risk of appearing superficial, the details of each development must be omitted, but I hope the reader can get a fair picture of their importance.

Cast iron is, of course, produced in a foundry and the foundries of the United States are continuing and will continue to produce thousands of tons of the old-fashioned brittle cast iron which you find described in your engineering handbooks. The word "progress" is unheard in many of these foundries.

On the other hand, there are foundries in increasing numbers which are equipped with chemical and physical laboratories and are manned by capable metallurgists. These have broken away from the old traditions and have proceeded to make castings of greater engineering value. The product of many of these well-managed foundries is excellent; any haphazard methods will make a product that is so variable it cannot be relied upon.

The greatest single development in the foundry in years has been the improvement in

physical properties resulting in the term "high test cast iron." Now, this may mean a number of things. In general, any gray cast iron with more than 40,000 psi. tensile strength is termed "high test cast iron," but there are a number of foundries which are able, with surprising uniformity, to produce iron of 50,000, 60,000, or even 70,000 psi. tensile strength.

It has been fairly well established that under adequate supervision a tensile strength of 50,000 psi. can be attained without the use of alloying elements. However, not a few foundrymen find it necessary to use considerable percentages of alloys to obtain even as much as 40,000. Melting methods have a decided influence on the ability of a foundry to produce high physical properties, but in my opinion this has been given undue importance because the improved properties of metal melted in other types of furnaces than the cupola can be attributed in some part to the greater metallurgical skill of the operator competent to handle these other types of furnaces.

It must be remembered that in order to attain high strength castings, easy machinability must be sacrificed. An engineering department will demand high strength castings and a few days later the machine shop will be complaining that the castings are difficult to machine. That's to be expected, and there is no easy answer to this difficulty. An iron of 60,000 to 70,000 psi. tensile strength must have a hard matrix similar to that of heat treated, high carbon steel. Its hardness may run as high as 300 Brinell, which is extremely difficult but not at all impossible to machine. You cannot expect to get very good results machining high test cast iron with high speed steel tools and no coolant. Instead, the machine shop should use cemented carbide tools with an abundance of coolant solution, and the tools and machines should be sturdy ones to take the increased tool pressures required.

Heat Treated Gray Iron

There are many other developments in high test cast iron which are of technical interest but I must pass over them in order to mention a field of endeavor which has been inadequately exploited to date. I refer to the field of heat treated gray cast iron. This operation can take a number of forms, ranging from an annealing treatment to soften the castings, to a quench and draw which will make them file-hard. I am still referring to iron which is gray as cast.

The tensile strength and hardness of gray iron can be increased by quenching in oil from approximately 1600° F. and drawing at a temperature in the neighborhood of 800° F. This hardening operation becomes more difficult when the silicon content exceeds 2%. If the iron is quenched only and not drawn, the metal will be under such internal strain that the tensile figures will be reduced, but if the heat treatment is properly conducted an increase of about 10% will be obtained. Hardening and drawing is especially beneficial to iron with a total carbon content of 3% or less. Such a metal has many uses, since it is extremely wear resistant and can be used for dies, cams, and other parts subjected to wear.

Certain grades of high test cast iron, particularly those containing alloys, frequently have a hardness, as cast, of 300 Brinell or over. Their tensile properties are excellent but the metal cannot be economically machined. A

This Alloy Cast Iron Clutch Plate Has Excellent Strength, Wear Resistance, and Toughness. It contains 0.27% chromium and 0.23% molybdenum

heat treatment to reduce the hardness from 300 Brinell to 240 Brinell will result in a great improvement in machinability and only a moderate reduction in ultimate strength. This is in the nature of a drawing operation to soften the matrix and is conducted at temperatures below 1300° F. The exact temperature and the time of treatment depend upon the type of metal and the percentage of alloys. In general, the longer the heat treatment and the higher the temperature, the more tendency there is for some of the carbon combined in cementite to revert to the graphitic form, which reduces the tensile strength for the same reason that low carbon steel is weaker than higher carbon steel.

Chromium Stabilizes Carbide

This tendency for cementite to revert to iron and carbon during annealing can be counteracted by adding 0.5 to 1.0% of an alloying element such as chromium. Carbides containing chromium seem to be much more stable. Such an iron can be heat treated into extremely tough, high strength material by holding at 1250 to 1300° F. for a period of time. This converts the pearlite in the cast matrix into a mixture of ferrite and cementite particles, in exactly the same way that toolsteel can be spheroidized to increase toughness and aid machinability. The resultant metal has high strength, excellent toughness, and some slight measure of ductility. It is easily machined and still retains good wear resistance.

Heat treatment of cast iron would be much more general if it were not so expensive for small batches. Commercial heat treaters frequently charge more for a hardening and drawing operation on small lots than the foundry does for the production of the castings. The spheroidizing operation described above, being confined to temperatures under 1300° F. with no subsequent quench and draw, offers an economical method of obtaining high strength and toughness in cast iron, without the penalty of difficult machining.

Many people attempting to use hardened gray cast iron where extreme wear resistance is required have been disappointed in the hardness obtainable in such things as machinery cams, gears, cylinders, and machine ways. Castings which have been heat treated in accordance with instructions fail to show the proper hardness after quenching. This is usually due to one or the other of two factors. In the first place, cast iron has a higher critical point than steel because of its higher silicon content and must be heated to a higher temperature before quenching; 1600° F. is usually adequate but we have encountered instances where even higher temperatures must be attained. Furthermore, the castings must have an opportunity to soak at this temperature so that the heating is uniform throughout. It is also important that the casting be quenched before the surface has had a chance to cool, during removal and handling; if the surface layer has a chance to air cool it will not harden, although the core of the casting may reach a satisfactory hardness.

The other reason why suitable hardness is sometimes lacking is associated with the fact that cast iron is an extremely high carbon material. In fact, it will range anywhere from 2.8% to 3.5% in total carbon content. Furthermore, the graphite being exposed on the surface of the metal permits decarburization to proceed at a very rapid rate. The so-called reducing atmospheres of many heat treating furnaces actually are oxidizing to the graphite and the combined carbon of the cast iron. Even an atmosphere mildly carburizing to soft steel can decarburize cast iron.

Most gray iron castings to be hardened are of fairly heavy section. Several hours are required to bring them up to the quenching temperature and in that length of time metal $\frac{1}{32}$ in. or even $\frac{1}{16}$ in. deep will lose its carbon, leaving a soft, spongy surface which almost can be scraped off with a penknife. Therefore unless the heat treater has a furnace with controlled artificial atmosphere he would be wise to pack the castings in carburizing boxes with partly spent carburizing compound, or at least with a copious covering of cast iron borings. Care must then be taken to allow sufficient time for the *casting* to come up to the quenching temperature and no time must be lost in quenching it after the box containing it is removed from the furnace.

Heat treated cast iron has a tendency to increase in size during the hardening process. Much of the growth can be avoided if the part to be heat treated is first completely annealed, by heating for three or four hours at 1350° F. The casting can then be machined with great ease and the heat treatment will result in a minimum of distortion and growth.

There are numerous other interesting developments in gray cast iron but time does not permit discussing them. I might mention in

Plate of Malleable Iron, ⅛ In. Thick, Rolled From a White Iron Billet 1¼ In. Thick. The bent piece was cut from the edge and bent cold

passing the high nickel and chromium irons which are martensitic and austenitic in the as-cast conditions. There have also been some interesting developments in the use of copper as an alloying agent, either alone or in combination with other elements.

Special Malleables

looked by metallurgists, yet it offers interesting

There remains the field of white cast iron to be considered. This has been largely over-possibilities of exploitation. To the average metallurgist white iron has two applications: *(a)* White iron castings, such as grinding mill balls and cleaning stars, where a hard, wear resistant material is required which does not have to be machined; and *(b)* white iron as the base metal from which malleable cast iron is produced by annealing, and in which the combined carbon is completely decomposed into ferrite and temper carbon.

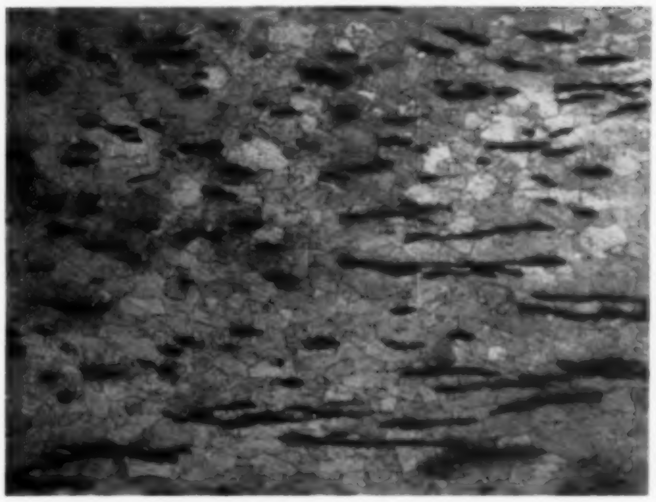
During the last ten years considerable progress has been made in investigating the properties and production of alloys containing *both* temper carbon and combined carbon. This commercial material is now known by the term "pearlitic malleable."

In some processes the castings are completely malleableized and are afterwards reheated above the critical temperature to redissolve a portion of the temper carbon as combined carbon. This is retained by rapid cooling, with the formation of a pearlitic matrix.

By another process the white iron is incompletely malleableized, with the result that the castings as cooled contain temper carbon as well as combined carbon which has never been decomposed. Under this procedure there are two principal variants: *(a)* The metal is of normal malleable analysis but is given an incomplete heat treatment so that combined carbon remains in the castings. The other process *(b)* starts with an analysis which will not completely malleableize under normal conditions, with the result that during the heat treatment there is no danger of complete malleabilization.

It is necessary for the engineer to picture pearlitic malleable as a graphitic steel. All of the castings will contain graphite in the form of temper carbon but the character of the matrix will vary in as many different ways as steel will vary. For instance, the matrix can be almost completely ferritic, in which case it would correspond to an S.A.E. 1010 steel, or it can be completely pearlitic, in which case it would correspond to an S.A.E. 1080 or 1090 steel. The combined carbon can be in pearlitic form, or in the form of martensite, troostite, sorbite, and, under certain circumstances, austenite.

If alloys are added, special properties can



Rolled Malleable Iron, Etched, 100 X

be obtained. For example, a pearlitic malleable iron analyzing 4% manganese and 2% copper is almost completely austenitic after quenching, non-magnetic, soft, and relatively unmachinable, similar to a quenched manganese steel.

The physical properties of these various pearlitic malleables will range from the low of malleable iron (approximately 55,000 psi. in tension) to a high of 120,000 possessed by a martensitic "pearlitic malleable." The ductility and other physical properties bear much the same relationship to each other as do corresponding properties in corresponding grades of cast steel, except that due to the presence of temper carbon the ductility is reduced.

A very useful form of pearlitic malleable is that in which the matrix consists of spheroidized cementite in ferrite, similar to that produced by a softening anneal on alloy cast iron. A metal of this type can be produced on a commercial basis to average over 80,000 psi. tensile strength and 15% elongation in 2 in.

It is needless to say that the exact field of usefulness of these heat treated, white iron alloys has not been adequately investigated, although a number of producers are already turning out respectable tonnages for a wide variety of applications.

Rolling Plates and Shapes of White Iron

The analogy I have made in the recent paragraphs between pearlitic malleable and steel can be carried even further than is normally suspected. I refer to the fact that we metallurgists have always thought of gray cast iron and white cast iron as being of use only in castings. This is not the case, however, as I intend to show.

Both gray iron and white iron are relatively non-ductile at ordinary temperatures. In fact, there are numerous references in the literature to the fact that white iron is "incapable of being worked at any temperature." It now appears, however, that at temperatures well above the critical, but below the solidus temperature, white iron billets become relatively plastic and can be rolled into sheets, bars, or structural shapes in the same way as steel billets.

You may be interested in the series of steps by which the method of rolling cast iron was developed.

Our foundry had a customer who was interested in a purchase of malleable iron in sheets, roughly 48 in. square and 1/4 in. or 3/8 in. thick. Naturally, during the depression we were willing to try anything and we attempted for a considerable period to produce these sheets in sand molds. Of course, the metal solidified as white iron and was extremely brittle. The strains set up as the casting cooled were so great that when it was removed from the mold it had frequently broken into two or three pieces. Numerous changes in the method of pouring finally yielded a few castings which were, apparently, free from cracks. However, when these were removed from the annealing ovens after malleabilization, they were broken in several places. This we attributed to non-uniform heating in the oven, and the casting cracked from the strains set up as the temperature rose.

It would take too long to go into all the attempts we made, such as putting undulations and ribs on the castings to improve the situation. It is sufficient to say that commercial success was never attained.

We could hardly escape the thought, "How much simpler it would be if malleable iron could be made in the form of billets and then rolled out into sheets of the desired size." The idea appeared preposterous at the time but we, nevertheless, determined to conduct some experiments along that line. Our foundry does not have any rolling mill and it was necessary to locate a suitable mill where experiments could be conducted with secrecy.

It is probably fortunate that we were foundrymen, rather than steel mill operators, or the idea would not have survived. We planned to roll both malleableized iron and white iron at the same time and we suggested this to the

cooperating steel company. We found a decided reluctance to permit us to use their equipment. The management was quite frank in stating that we were crazy; naturally everyone knew that white iron could not be rolled and practically everyone was aware of the fact that malleable iron, if heated to a high temperature, became brittle.

We finally agreed to purchase a set of rolls, which if damaged would be our own loss. We rented the mill, with the necessary labor, and we were to provide the necessary supervision.

On the day set for the rolling we were on hand after an early breakfast and I must confess that when we sent out for sandwiches at noon our success was negligible. It was rather disappointing to have a glowing billet go in one side of the mill and come out from the rolls on the other side broken into 40 or 50 small pieces. The afternoon, however, was crowned with success as we corrected rolling temperatures, percentages of reduction and rolling speeds, and it was with considerable satisfaction that we left the mill late in the evening to heat treat the specimens so as to get the desired physical properties and metallurgical structure.

Minor Production Problems

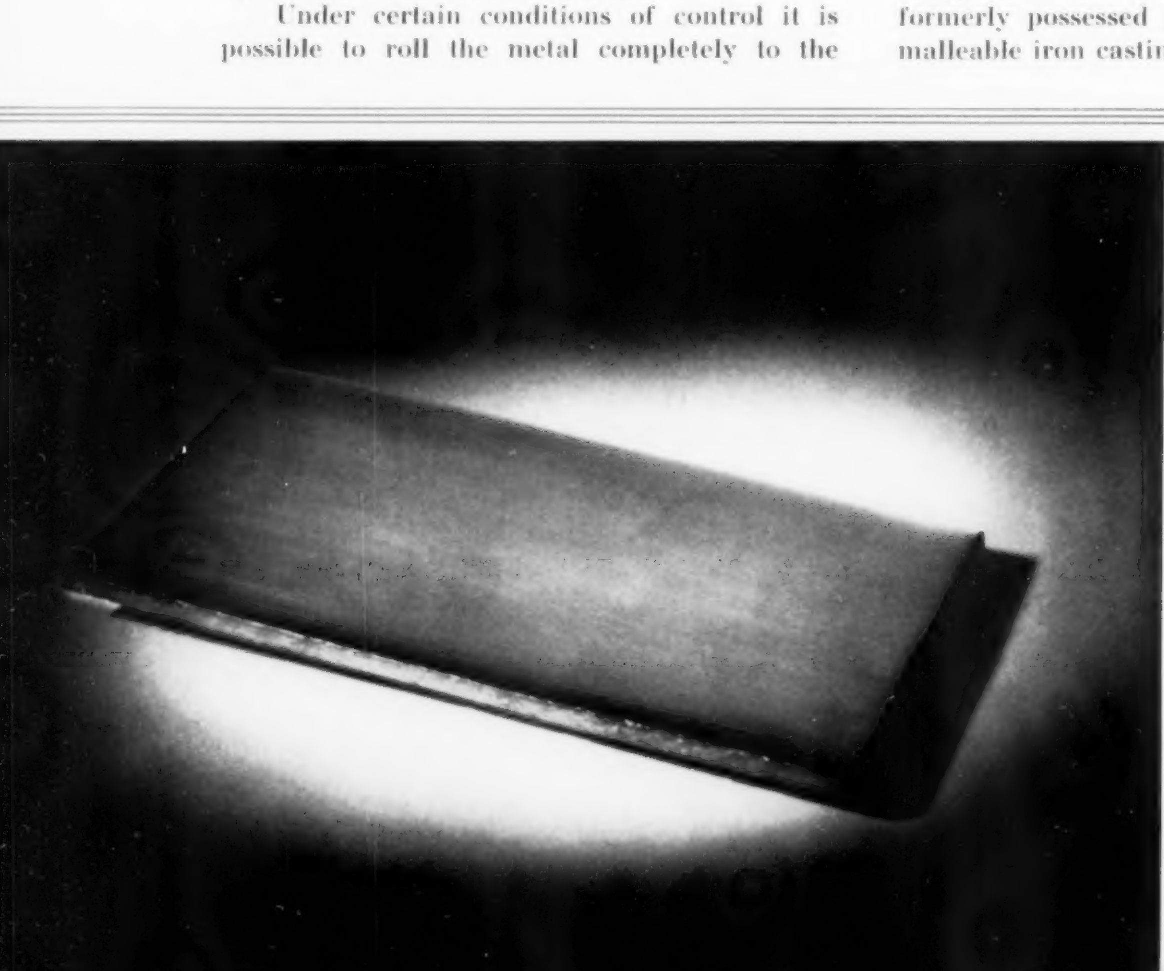
This development, which was discovered at about the same time by three independent groups of investigators, has shown that white iron offers only minor problems of technique to the rolling mill operator, but the product opens up a whole new interesting field.

Under certain conditions of control it is possible to roll the metal completely to the desired shape as white iron, which subsequently can be heat treated to precipitate temper carbon and to form malleable iron or pearlitic malleable, whichever the manufacturer desires. Or, under other conditions, particularly of analysis, it is possible to roll the metal down to shape and at the same time almost complete the formation of temper carbon while the metal is being rolled. It then requires only a short heat treatment to leave the structure of the matrix in the desired form. It is interesting to note that when graphitization occurs during rolling, decomposition of cementite occurs in a mere fraction of the time which would have been required had the metal been subjected to heat treatment only.

Rolled malleable iron and rolled pearlitic malleable have a microstructure similar to that of the cast material, except that the deposits of temper carbon are greatly elongated, depending upon the extent of mechanical reduction. The fracture has a striking resemblance to the fibrous fracture of wrought iron, the elongated deposit of graphite acting similarly to the elongated deposit of slag in wrought iron.

Tests conducted on the rolling of gray cast iron have also been successful but it is doubtful if there is sufficient advantage in rolled gray iron to make it desirable over the more easily handled rolled white iron.

The field of usefulness for this material has not yet been adequately investigated. It is believed, however, that it inherits the corrosion resistance possessed by the cast metal and also many other of the useful special properties formerly possessed by conventional gray and malleable iron castings.



Sample of Rolled "Pearlitic Malleable," 1/4 In. Thick, Rolled From a Partly Graphitized Billet 1 3/8 In. Thick. The surface has been highly polished. The edge in the foreground is the original edge of the plate, as rolled, and is free from edge cracks

Cooperative research prior to 1927 led to the adoption of a standard method for testing the life of resistance wires suitable for domestic appliances. Utilization of this test for production control has enormously improved the quality and serviceability of such materials. It is now also possible to estimate minimum life at operating temperatures from the test figures derived at much higher ones. The technique is being adapted to resistors of large diameters, suitable for metallurgical furnace work, which would endure an indefinite time under the testing conditions which will cause failure in fine wires only after 150 to 200 hours

ESTIMATING LIFE OF ELECTRICAL HEATING ELEMENTS

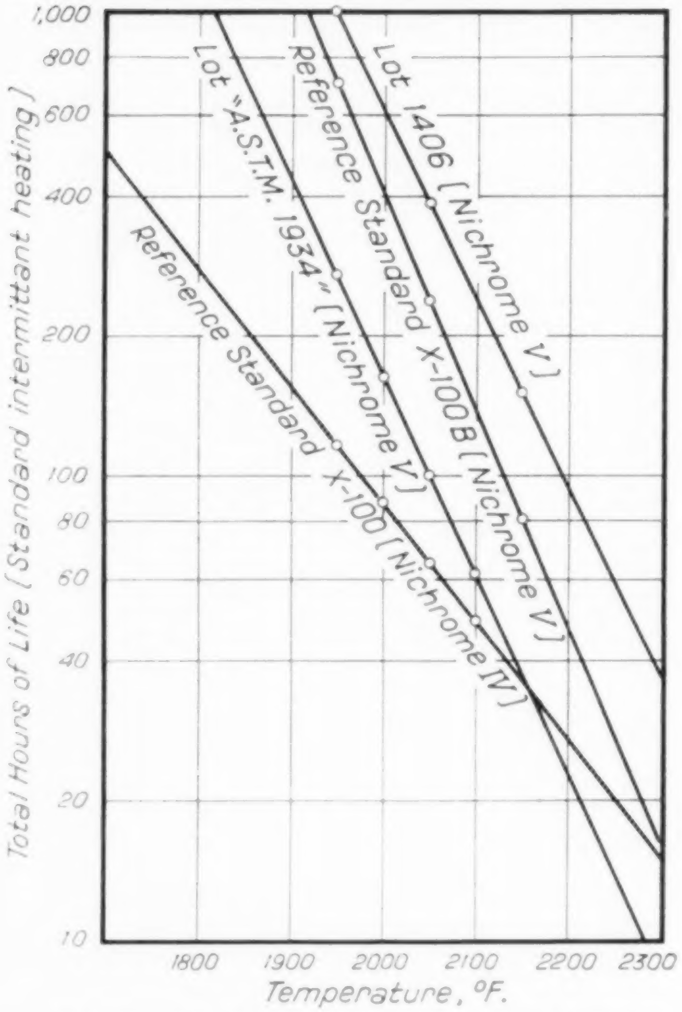
BY FRANCIS E. BASH, DRIVER-HARRIS CO.
Manager, Technical Department Harrison, N. J.

THE electrical heating industry, which utilizes a wide variety of applications from toasters to electric furnaces, has always been vitally interested in the life and maximum operating temperature of the heating unit. This interest was so strong that the American Society for Testing Materials at the request of the industry in 1925 appointed Committee B-4 to work out test methods for the life of the resistance alloys then in use.

The author will show briefly the steps of development of this standard A.S.T.M. life test and the resultant improvements in the resistors. These lead up to the conclusion that it is now possible to foretell within reasonable limits the life expectancy of a wire at *any* temperature, when the standard test data are known. (It is presumed, of course, that the conditions of oxidation be similar and that no corrosion be present.) It is reasonable to expect that it should also be possible to judge both the ability of other sizes and shapes to withstand oxidizing conditions, and to anticipate the effect of unit temperature on expected service.

Prior to the adoption of the A.S.T.M. life test in 1927, there was no way by which either the alloy manufacturers or the ultimate consumer could judge the relative merits of the various alloys on the market, or estimate with any degree of accuracy the life of a heating element under any condition of use. Design was based on experience and sometimes not-too-reliable guessing. Committee B-4 had spent two years of experimental work with this method and arrived at a tentative standard for testing the oxidation resistance of wires to be used in electrical appliances. In its latest form the test method is described in "Standard Accelerated Life Test for Metallic Materials for Electrical Heating", A.S.T.M. designation: B76-36. (A.S.T.M. Book of Standards, Part I, 1936, page 734). Its development was described in detail by F. E. Bash and J. W. Harsch in *Proceedings*, A.S.T.M. for 1929, page 506. Further discussion may be found in other papers by the same authors before the International Association for Testing Materials, The Hague (1928, Vol. 1, p. 163), and in London (1937, Book 33, Group A-1).

Testing of experimental melts by this standard method has led to very great improvement in the various heating alloys, chief of which were the 80-20 nickel-chromium and the 60-16-24 nickel-chromium-iron varieties. In the case of one company's product, the meas-



Improvements in Processing 80-20 Nickel-Chromium Have Largely Improved the Resistance Wire Now Available. Compare old reference standard X-100 with new X-100B. Circles show test life (A.S.T.M. standard) in hours for temperatures noted on wire 0.025 in. diameter

ured life has increased by 1000% at the present date. Other manufacturers can report very marked improvement also. This is a remarkable accomplishment and a direct result of the adoption of the standard life test.

It now appears that it is possible, for sizes of wire suitable for household appliances tested under prescribed conditions, to accurately foretell their life under the same conditions at other temperatures.

In the course of 12 years of testing in the laboratories of the Driver-Harris Co., a great deal of data has been taken and many tests made at different temperatures on pieces of wire cut from the same spool. When life testing was started, a piece of 0.025-in. diameter "Nichrome IV" (the designation of the 80-20 nickel-chromium alloy then used) was selected to be used as a standard of comparison, and all tests on other wire of the same nominal alloy were reported as per cent of this standard.

Improvements in melting and deoxidation practice and in further processing of the Nichrome IV wire increased its life so much that the new process 80-20 Nichrome was given the designation "Nichrome V." It was then found necessary to increase the temperature in the standard life test so that the total time of test would be within 100 to 150 hr. Since then, on account of further improvements, the temperature has been again increased and now results of approximately 200 hr. total test life are obtained at a temperature of 2150° F. This compares with 100 hr. test life at 1950° F. when the test was originated.

It has been necessary in the meantime to select new standards of comparison. The original Nichrome IV was designated X-100, and this has in turn been supplanted by Nichrome V, which is designated X-100A and X-100B. These have been carefully inter-checked so that reference can still be made to the original standard.

Results of many tests at varying temperatures were plotted on semi-logarithmic paper and it was found that the relation between test life and temperature took the form of:

$$\log L = T\ (\log a + \log b)$$

where L = total hours test life,
T = test temperature in °F.
a and b are constants

The curves were found to be straight lines on semi-logarithmic coordinates. It therefore appears possible to determine the test life of a wire under the same conditions at other temperatures by extending the lines. Upper and lower limits at which the curve will deviate from a straight line are at temperatures near the melting point and where oxidation begins.

It was found, as a result of tests on a number of lots, that alloys of the Nichrome V type all had the same slope or very nearly so, and that the earlier Nichrome IV wire had a definitely different slope, as shown in the first curve.

When we speak of Nichrome V we mean type alloys with a nominal composition of 80% nickel, 20% chromium, having slight variations in the minor ingredients. It will be noted in the first curve, in which the hours of test life vs. temperature are given, that the various lines for Nichrome V are approximately parallel, and the Nichrome IV curve has a much flatter slope. It will also be noted that the three different Nichrome V's vary quite widely in life.

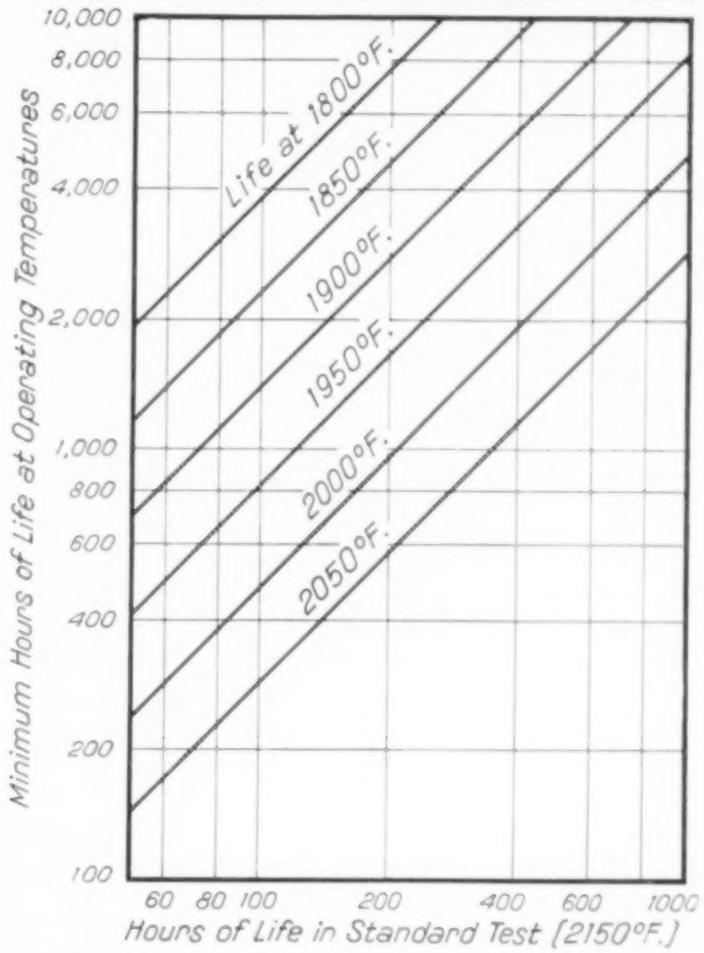
This is representative of the alloy as it has been developed through varying stages. The "X-100B" was a later development than the "A.S.T.M. 1934" and the "Lot 1406" represents still later production.

In view of the varying slope of these curves for Nichrome IV and Nichrome V, it would be very misleading to try to draw conclusions on the relative quality of these two alloys at a temperature of, say, 1800° F. from a life test made at 2150° F. It is for this reason that it is important to make life tests at a number of temperatures, to establish the slope of the curve before making comparison.

Below are tabulated the calculated slopes for a number of samples.

Sample No.	Alloy Type	Slope (Per °F.)
35236	Nichrome V	0.00426
1406	Nichrome V	0.00412
A.S.T.M. 1934	Nichrome V	0.00426
X-100B	Nichrome V	0.00459
X-100	Nichrome IV	0.00248

In view of the fact that slopes of the test curves of Nichrome V appear to be of the same order, it is assumed that the slope of X-100B, which is the present standard of comparison, is representative of the 80-20 alloy in its modern form. The second curve sheet is plotted on this assumption, and it shows the expected test life of a wire at one of the temperatures indicated when the number of hours of test life at the standard test temperature of 2150° F. is known.



Curves Showing Minimum Life of Modern 80-20 Nickel-Chromium Resistance Wire at Other Temperatures When the Life Has Been Determined in the Standardized Procedure at 2150° F.

It must be remembered that the standard test is conducted on wire No. 22 American wire gage and under the most severe oxidizing conditions that can be devised. Committee B-4, while developing the life test, tried many cycles of heating and cooling and definitely established that the cycle of two minutes heating and two minutes cooling gave the shortest life for wire of this approximate size.

It has also been established by Committee B-4 and verified by tests made in Europe, that the effect of size of wire is immaterial between 18 and 24 gage (0.040 and 0.020 in. respectively). It is therefore possible to say that for normal sizes of wire used in heating appliances, where the wire is used under strictly oxidizing conditions, the minimum life at the operating temperature would certainly not be less than that indicated in the figure above, because under normal conditions of use in heating appliances, the element is held at temperature for much longer periods of time than two minutes.

The life of a wire in service depends upon two factors. These are the length of time at temperature and the number of times that it is cooled. Tests made some years ago indicated that the relation between the life of a wire which was continuously heated and one which was tested under standard A.S.T.M. conditions, was of the order of 20 or 30 to 1. A few interruptions of the circuit of a continuously heated wire will reduce its life to one-quarter or one-half. It would therefore be logical to assume that the life of the heating element in an appliance would certainly be a number of times longer than that of the same wire when tested at its working temperature but otherwise standard life test conditions (2 min. on, 2 min. off).

The chief point which has been established by the first set of curves in this article is that there is a definite and simple relation between life and temperature for each type of alloy. It should therefore be possible to say, under similar conditions of service and in cases where

corrosion is not present, what the life of an element might be at one temperature, if it were known at another temperature. It is necessary, of course, to establish carefully the slope of curve for each alloy by many tests at three or more temperatures. If the points do not fall in line, it indicates inaccuracies in the test.

While the above data and discussion are concerned principally with a small range of sizes of wire suitable for appliance manufacture, it indicates the possibility of applying the knowledge we have gained to any size or shape. It only remains to determine the life of some other sizes. This work has been started on resistors of No. 8 gage, applicable to small furnace work. The adjoining halftone shows the set-up. Hoyt and Scheil have described a test apparatus and procedure (of which the left half section is a copy) in "A New Heat Resistant Alloy," *Transactions*, December, 1935. The right section of our equipment uses the same general procedure but the shape of the sample under test is in the form of a hairpin suspended vertically. These tests are run at constant temperature and are controlled by photo-electric cells as described in the paper just quoted.

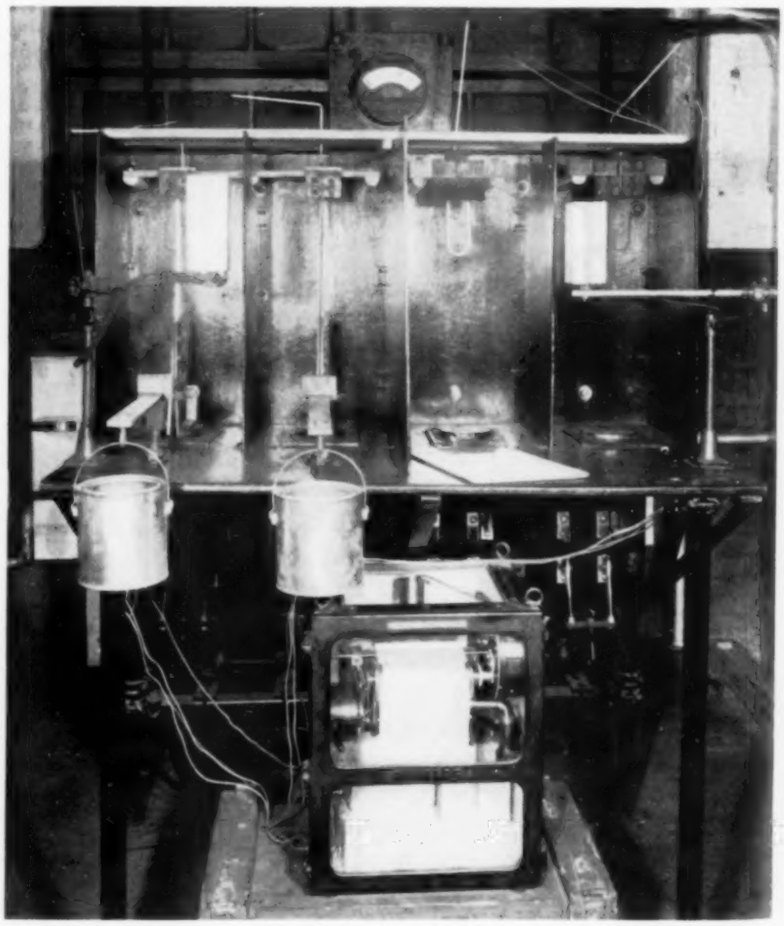
A view of some of our life testing panels is also given. Expansion and growth may be determined by means of the telescope shown, which is leveled and may be adjusted in a vertical plane. It contains a cross hair and is sighted across the weight on the wire at the cross-section paper on the back panel. The stalls at left indicate the mechanism for recording the end of the test. The weight on the end of the wire releases a trigger, which causes a mercury switch to tilt and start the electric clock placed above the case. Knowing when the test was started, the observer can figure back from his watch time to determine the actual end.

Some samples under test are enclosed in a metal case and the temperature is read through a window. Such tests are being conducted in various furnace atmospheres.

Designers of heating elements can make use of the life test data now available and take advantage of the increased life of alloy by running at a higher watt density. They can also estimate the expected life of an element when it is operating at a new temperature, knowing the life obtained under the temperature conditions previously encountered.

Procedure followed in the plant of Driver-Harris Co., by which the quality of electrical heating alloys is controlled, is as follows:

Our methods of life testing or endurance testing are fundamentally the same as the A.S.T.M. standard, but revised slightly for greater convenience and speed. The panels or stalls are arranged facing each other, 36 on each side. The room is practically free from draughts; and each position is closed on all sides but the top and has glass in front. Placed on top of each test panel is an electric clock, which starts when the wire fails. In production control a heat is cast, one ingot is rolled to rod and a portion of the rod drawn to the test size, 0.025 in. diameter, and a life test made immediately. Two samples are tested and no further work on the heat is done in the mill until the life test is

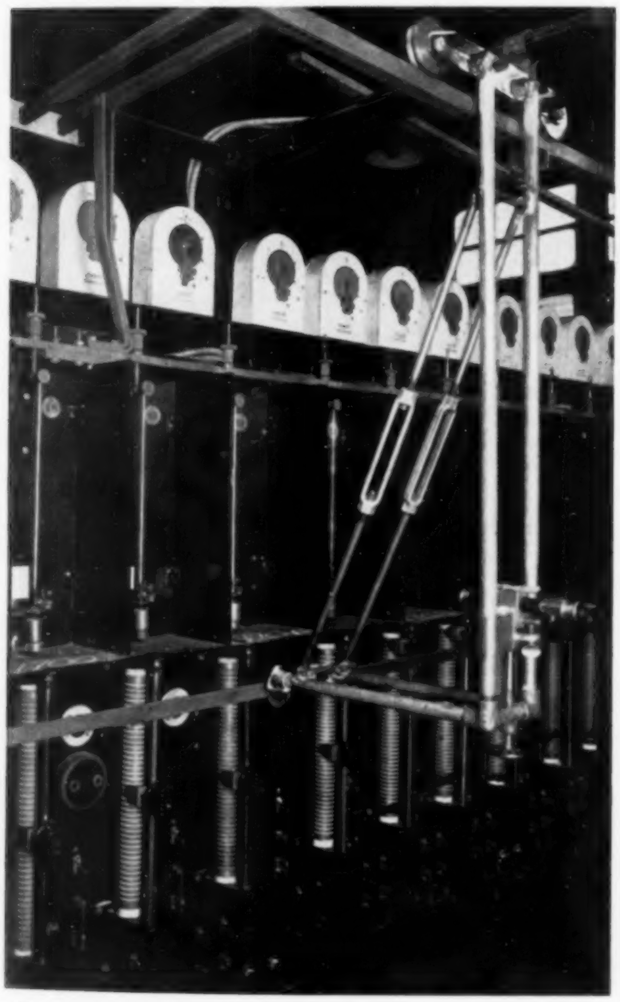


Bench for Life Test, Modified for ⅛-In. Wires as Suggested by Hoyt and Scheil. Left pair of stalls have straight wires; right pair have unloaded loops. Temperatures are controlled by photo-electric cells

completed. The minimum limits allowed for approval are now many times higher than when this test was incorporated. Any material falling below this minimum life requirement is scrapped.

Weekly tests are run on a standard wire of comparison and all tests are reported in terms of this standard, as well as in hours. In control work it is, of course, essential that the preparation of the sample for life test be completed as quickly as possible, as otherwise a large inventory of unapproved ingots will accumulate.

In conclusion, it now appears that if sufficiently careful life tests be made on an alloy in accordance with the A.S.T.M. method, a life-temperature relation can be established which will greatly assist in the design of heating equipment and will help in estimating the service that can be obtained from a heating element under varying conditions of temperature.



Bank of A.S.T.M. Standard Life Tests. Creep of the wire is measured by telescope (level), sighting past lower clamp to target mounted on rear of stall

MAGNESIUM FROM MAGNESITE

BY W. S. LANDIS

Abstract of paper before American Electrochemical Society, 72nd Meeting, St. Louis

SMELTING of magnesite into magnesium metal by electric furnace processes has been successfully achieved at Austro-American Magnesite Co. of Radenthein, Austria, at costs competitive with that of either magnesium or aluminum from more conventional processes. There is a rapid development of this new process in several parts of the world, and its production volume bids fair to equal that of the older electrolytic process. Magnesium produced by this distillation process is particularly sound in the form of ingots and castings.

The principal ore of magnesium is magnesite; such a high grade carbonate is readily calcined to oxide. The principal impurities are calcium carbonate, iron carbonate and clay. It is necessary to calcine at high temperatures to be certain that all volatiles are removed, that is, to "dead burn" it.

Three parts of magnesium oxide are reduced by one part of anthracite at about 4000° F. Magnesium and carbon monoxide are thus formed within the arc, both leaving in the form of vapor. In fact, all the charge fed to the furnace is vaporized. Vapors reaching the condenser (a horizontal cylindrical tank attached to the side of the furnace itself) are therefore diluted with those from the impurities in the ore, and under these circumstances, the dew point of the magnesium vapor is about 1800° F. and complete condensation occurs during further cooling to 1200° F.

Such finely divided magnesium is easily reconverted to oxide by carbon monoxide, thus reversing the reaction at the focus, so condensation represents a complicated problem. Ordinary methods of cooling yield only magnesium oxide. The problem was most ingeniously solved by injecting undercooled hydrogen into the vapor stream as it leaves the reduction furnace, thus suddenly lowering the temperature of the vapor to 350° F. Such sudden cooling, and of necessity to such a low temperature, produces *(Continued on page 210)*

A MAN OF METALS

Photo by Bachrach

Eugene Gifford Grace

PRESIDENT, BETHLEHEM STEEL CORPORATION

LEAN AS AN ATHLETE in training, with keen black eyes and a rugged jaw, Eugene Gifford Grace, president of Bethlehem Steel Corporation, typifies the modern industrial executive.

Those close to him say that he has never pounded a desk or lifted his voice above the normal number of decibels, yet under his regime Bethlehem has increased from an annual capacity of 848,000 tons in 1913 to substantially more than 10,000,000 in 1937.

When he became president of the Corporation he adopted the policy of conducting its business through an executive group located at Bethlehem, Pa., away from a metropolitan center. That policy of close association and contact among the principal executives permits the coordination of all branches of the enterprise by a single directing group. This form of organization, while perhaps not unique, was not the form generally used in the steel industry in the management of scattered units of a single parent company, but it has proved highly efficient, and in Mr. Grace's opinion it has been the most important single factor in his development. Each executive head is fully responsible for his own line of activity. Mr. Grace holds that the corporation can function best as a group of creative minds with each individual given the opportunity to contribute his best in consultation with the others.

This spirit of mutual understanding and coordinated responsibility permeates all phases of the Bethlehem organization. Each man is encouraged to take as much responsibility as his talents will permit, and it is recognized that the private soldier may readily have some useful point of view which the brigadier generals have overlooked.

Constant open-mindedness on the part of President Grace has given this hard-hitting, intent executive his reputation for diplomacy. He is impatient with idle chatting, has no fund of small talk, but is always interested in the other man's point of view. He is an ardent reader of the newspapers, including those publications which are ultra-critical of business, believing that the ostrich has made little progress in evolution.

'Gene Grace is friendly with his industrial colleagues, is warm-hearted with the executives and employees of his Company, and is at his sternest before the camera or the portrait painter.

It is significant of the rise of technology in the business world that Eugene Gifford Grace was graduated as valedictorian of the class of 1899 at Lehigh University. The same summer he started work with Bethlehem Steel Co., running an electric crane. His main idea was to be valedictorian of each job that was assigned to him and to apply the utmost knowledge of science to the improvement of the business. He was moved rapidly through various assignments in the steel-making department and in 1902 was made superintendent of yards and transportation. With good prospects for the future he married Marion Brown of Bethlehem. The family home has always remained in Bethlehem, where two sons and a daughter were born and raised to maturity.

When Charles M. Schwab purchased the Bethlehem company in 1905 he aimed to develop the men then employed without bringing in outsiders. After trying out the Grace talents on the job of reorganizing mines in Cuba, Mr. Schwab made the young man general superintendent of the company, and a few years later president. At the age of 40 he was in charge of all the activities of the various subsidiary companies.

At the time, the industrial world was astounded to see a country boy whose business life had been limited to a small-sized city elevated to such a post. For E. G. Grace had been born in Goshen, N. J., a crossroads community, on August 27, 1876. His experience had been entirely outside of the world of Wall Street. But Schwab had always held that the industrial work of the country was usually achieved by men outside of the metropolitan centers and that the financial problems could be readily grasped when the need should arise.

This faith on the part of Mr. Schwab was justified by the young president promptly upon taking the helm. Within a year after Grace's appointment to head the steel company the World War began. Orders poured in upon Bethlehem and a huge staff had to be improvised rapidly. With the entrance of the United States into the conflict all the resources and facilities were virtually commandeered by the Government, and so effectively was the company administered that during the War period Bethlehem supplied 40% of the filled projectiles for field guns, one pounder size and upward, produced by the United States and 60% of the finished field artillery. In becoming head of Bethlehem Steel Corp. in 1916 Mr. Grace was in

charge of the shipbuilding plants, which delivered about one fifth of the output of the entire merchant shipping completed in the U.S. during the War as well as more than half the torpedo boat destroyers built during 1918 — the exact number being 26 in that one year alone.

Following the War the foresight of Mr. Grace was again exemplified in the decision to get back completely and immediately to a peacetime basis. Wreckers were busy smashing up machinery that made munitions. He did not want any tempting facilities standing around which would prevent clearing the ground for the peace. The Company's books were swept so clean of war business that the total value of munitions sold to foreign countries by Bethlehem since 1925 has been less than $400,000.

Deciding to find new markets and finding them are, however, two different things. Grace analyzed the situation. During the War he had found that the most economical procedure in expansion was usually to acquire existing plants where there was already adequate land, rail connections and some degree of other facilities ready to be developed. In this way the Corporation not only acquired physical properties, but also going concerns — good-will, an established list of customers, but most of all, a personnel which had the knowledge and ability to assist in the growth of the business under the new management. Hence Bethlehem's era of post-War commercial expansion has been the procedure of acquiring and developing existing companies. Upon the acquisition of the Lackawanna, Cambria and Midvale properties in 1922 and 1923 Bethlehem Steel Corp. undertook a construction program contemplating the modernization and development of the newly acquired plants, and the addition of finishing capacities both at these plants and at its other plants.

These properties were in the East, however, and Mr. Grace felt that a well-rounded producing organization should be better balanced, geographically. Accordingly in the subsequent years, Bethlehem has acquired producing and warehousing properties at three major points on the Pacific Coast. The Company likewise purchased McClintic-Marshall, with steel erecting and constructing facilities in major cities throughout the country as well as abroad.

Grace is a believer in "permanent values." He is impatient with the attempt in some directions to characterize certain ideals and virtues as "old-fashioned." He holds that permanent values do not become old-fashioned. They may be temporarily obscured or disregarded, but they are never discredited.

One of the permanent values is sound health. "A sound mind in a sound body" is a view which has held good through the centuries. He regards his program of daily exercise to be as important as any other activity on his calendar, for his own clarity in thinking and efficiency in business.

Grace believes that the Golden Rule is not only the paramount ethical principle, but also the basis of a well built industry. Under his direction, Bethlehem has been a leader in employee relationships. As long ago as 1918 Bethlehem workmen drew up their charter of employee representation, and as each plant has been acquired the employees therein have developed and put into practice their own plans of collective bargaining.

Similarly, Grace has encouraged the adoption of safety programs, the employees' relief plan, a corporation-wide system of old age pensions and other items of social security which were in force long before such activities were generally advocated.

In addition to Mr. Grace's leadership in labor relations he has been active in many other activities affecting the welfare of the steel industry as a whole. Much of his time during the depression was devoted to cooperation with the Government in efforts toward recovery. When he was awarded the Gary Medal of the American Iron & Steel Institute in 1934, he was cited "for a ripened, selfless and resourceful leadership in formulating principles of self-government for our industry under the Recovery Act."

One of his outstanding achievements has been reorganization of the American Iron & Steel Institute. During his presidency of that body, 1935 to 1937, many departments were amplified and others established. The Institute thereby became increasingly of service to the industry and to the public through its activities in research, in standardization and in better commercial practices.

President Grace's basic philosophy regards business activity as a public trust. His views may be summed up in a quotation from his address before the Iron & Steel Institute where he said, "We have a tremendous responsibility to conduct this great enterprise — this steel industry — in a manner eminently and jointly fair to the workmen, to the investors and to the public. These responsibilities and obligations are fundamental to all industry."

Railroad steel castings have grown from the size of automatic coupler jaws and draft rigging parts (husky as they are) to six-wheel trucks, where side frames, crossbars and bolsters are combined in one piece. Car underframes up to 50 ft. long, and tender frames almost as long and cast solid to form the bottom of the water tank, are commonplace. Marvels of the foundry art are one-piece engine beds, with cylinders, steam chests and boiler cradles integral with the foundation for drive wheels and drawbars. Mr. Sheehan shows how these latter castings have tripled the availability or annual mileage of locomotives

STEEL CASTINGS REPLACE BUILT-UP CONSTRUCTIONS

BY WILLIAM M. SHEEHAN, GENERAL STEEL CASTINGS CORP.
Manager Eastern District Sales — Eddystone, Pa.

THE steel casting has been in extended industrial use for less than 50 years, although it was introduced at a much earlier period. One of its most important fields, and the one principally treated in this paper, has been in railroad work where it performs many useful functions, for in common with other forms of steel, it inherently possesses high fatigue resistance, toughness and tensile values, all of which can be substantially increased by skillful metallurgy.

To appreciate the rapid strides which the use of cast steel has made in railroad work, it will be interesting to review car and locomotive construction as they were at the turn of the century.

Locomotives then were small, low-powered and thermally inefficient, runs were short and division terminals had to be located about 100 miles apart because road failures were common and constant attention was required. The foundation for the locomotive machinery was built largely of iron forgings with a few iron castings, the largest of which was the half-cylinder, then of very small size. There were, except for a few isolated ones, no steel castings on them. These locomotives could haul perhaps 50 cars of low capacity and these in turn were lightly built. Freight cars and locomotive tenders had arch-bar trucks and wooden truck bolsters; their underframes were of wood with steel plated wooden body bolsters. Passenger cars had wooden framed trucks and wooden underframes with steel plates as reinforcing pieces. Nearly all couplers were of malleable iron.

Costly maintenance of locomotive and tender foundations and trucks made it imperative that more efficient materials and forms be secured, and this resulted in the general adaptation of steel castings, which, up to that time, had been little used.

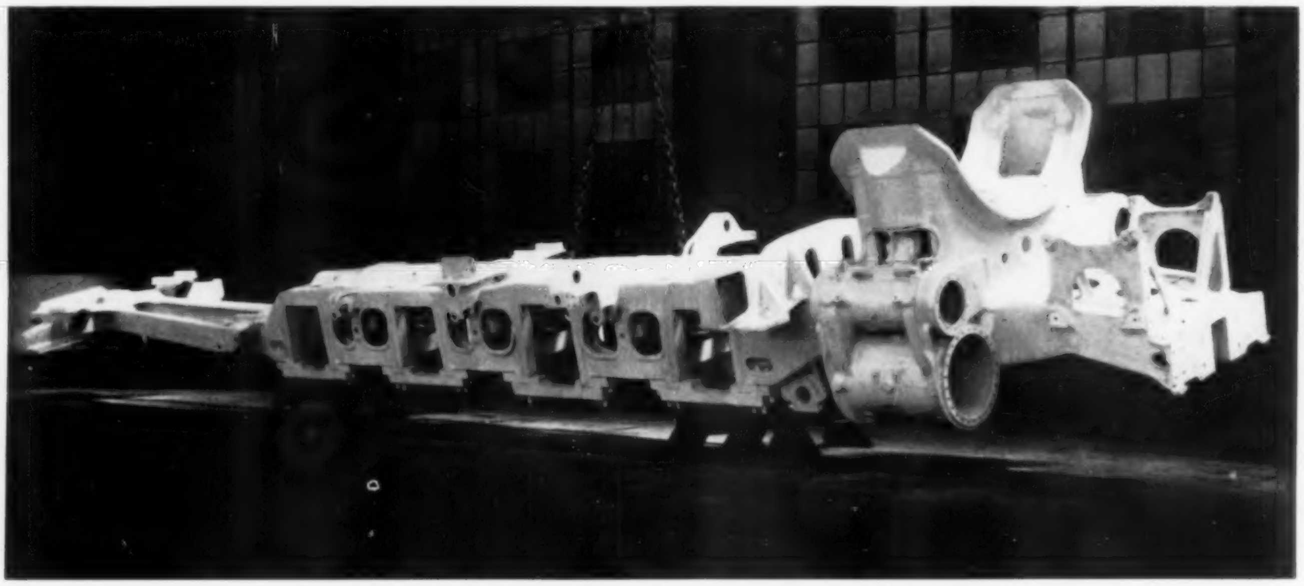
In detail, the previous form of locomotive machinery foundation consisted of two frames of forged wrought iron bars, which carried the boiler and the cylinders and had a few forged crossties to keep the frames in a parallel position. Enlarged locomotives required heavier frames. Finally the frame became a limiting factor in locomotive size on account of the difficulty and cost of forging it. In the middle nineties, railroad men and locomotive builders who had been observing the progress in steel making conceived the possibilities of cast steel

main frames. The first ones were on a six-wheel switcher built in the St. Louis Southwestern Railway shops in 1896, and this date began the move toward the locomotive of 1938.

It is fitting that a steel foundryman pay tribute to the progressive railroad men. During the past five years, the railroad industry has been truly reborn. As an example of the operating progress which has taken place, consider that only 15 years ago, seven steam locomotives successively were used to handle a New York Central through passenger train between New York and Chicago. Now there are but two and were it not for the change to electric operation through Cleveland, one modern steam locomotive could make the entire run with ease.

Several years ago, a man prominent in the automotive field took the railroads to task for lack of progressiveness. He entirely neglected to consider that the necessity of building railroad equipment for so much more severe conditions involves an entirely different treatment than is required in the automotive and aeronautical fields. In no undertaking is so much emphasis laid on safety as it is in railroad operation. The record is so nearly perfect that the public unconsciously thinks of railroad travel as accident-proof. Railroad executives therefore insist that every improvement in equipment and service, including lighter rolling stock and elimination of superfluous weight, be measured by its relation to safety.

As a matter of fact, during the past decade, principles developed in the automotive and aeronautical industries *have* been introduced into railroad equipment. But there is one striking dissimilarity: Railroad equipment must have a far greater degree of permanence built into it. The service life of a locomotive in years is several times that of an automotive vehicle or an airplane. Modern high speed locomotives make almost as many miles in a month as a passenger automobile does in the hands of the original purchaser, and as many miles in a year as a commercial motor truck piles up in its entire life!



Single Casting of Mild Steel for Union Pacific 4-8-4 Locomotive, Typical of Engine Beds Installed Under Modern Motive Power

These facts emphasize the importance of engineering design in steel castings for railroads (and other industries). Experience has clearly proven that proper *design* is of much greater concern to the user than either manufacturing or metallurgical practices, although the value of neither of these should be under-rated. The experience of one steel founder covering a period of more than 30 years indicates that over 80% of his casting difficulties were overcome by changes in design.

For instance, there are definite thicknesses below which steel casting sections should not be reduced. These minima vary with the size and shape of the casting and also with the experience and the practice of the particular foundry. It is essential that all passages in the mold be of sufficient width to prevent "freezing" before the

entire mold and the risers above it are filled. Advances in foundry technique and metallurgical practice have now made it possible to cast much thinner sections than was thought practicable only a few years ago.

Returning from this diversion to a roughly chronological account of the development of railway steel castings, it may be pointed out that side frames for freight car trucks were first made of iron-bound wooden timbers, then later of rolled steel arch-bar trusses when the wood proved inadequate. Subsequently, as weights of cars and speeds of trains increased, the hazards of the bolted arch-bar truck prompted the development of the cast steel side frame and also of the cast steel truck bolster. Many unsuccessful attempts have since been made to supplant both of these items with various forms of built-up riveted and welded construction; meanwhile, many improvements have been incorporated in the cast steel forms and their freedom from maintenance has made them the accepted standard. In fact, the built-up arch-bar truck is now outlawed.

Since 1905, when they were introduced, the truck frames, both four and six-wheel, of passenger cars have been almost without exception one-piece steel castings embodying not only the longitudinal and transverse members, but also many brackets for such auxiliaries as brake and spring rigging and train lighting. The associated bolster and spring plank have also followed the same unit principle. On the high speed, light weight trains recently introduced, many of these frames have been made of high tensile alloys for minimum weight. The box-section members of the castings provide ample beam and torsional strength.

Don't Hold Up the Locomotive

This might well be the slogan of every railroad man. The locomotive is potentially the most productive tool the railroad possesses. As the earning power of the locomotive depends on the time it is in service moving trains, every possible increase in availability, capacity and efficiency is diligently sought for and utilized.

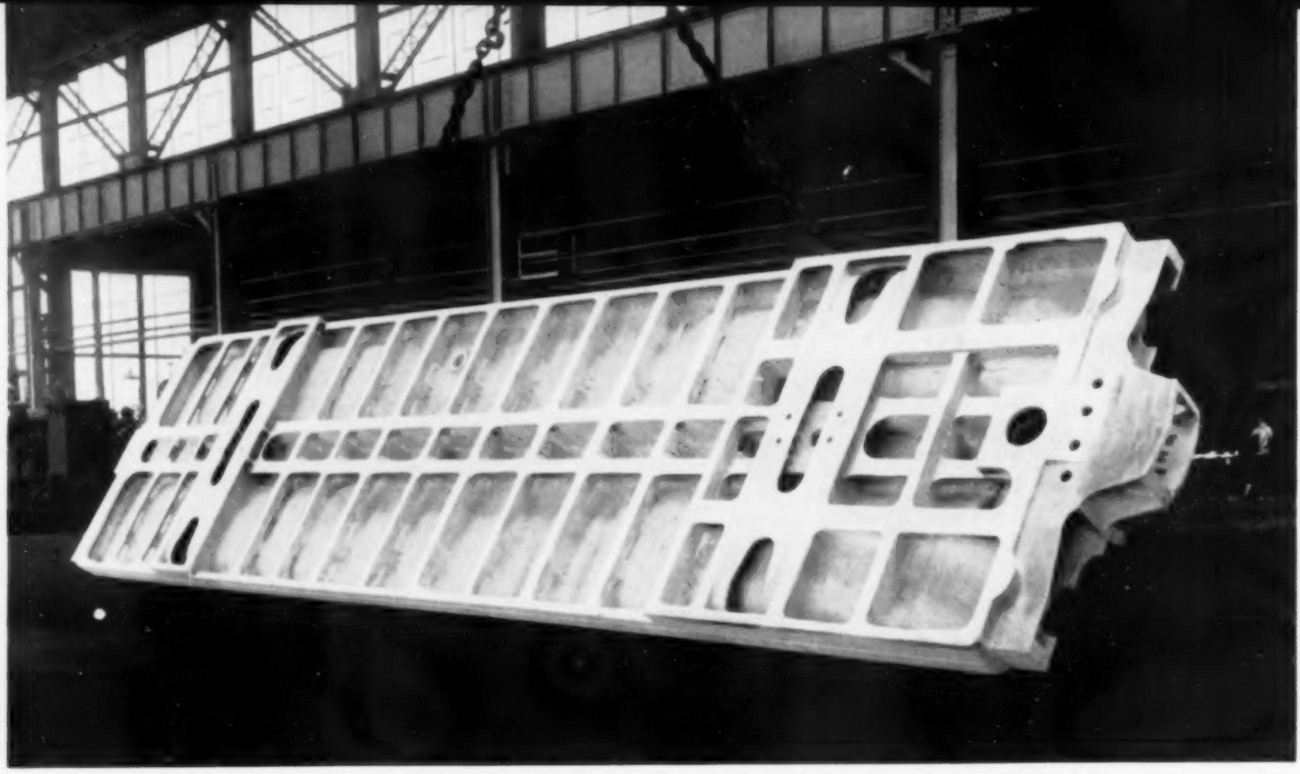
In conformity with this principle the entire under-structure of the modern locomotive and tender comprises integral cast steel foundations such as guiding, driving, trailing and tender trucks, locomotive beds, driving and truck wheel centers, pilots, ash pans, water bottom tender frames and stoker troughs.

Probably the outstanding example of a successfully proven large steel casting is the steam locomotive bed. This is now so generally used that it may be said to be a standard part of American railway practice. First introduced on the New York Central in 1924, it has been rapidly adopted by the large railroad systems of the United States, Canada and Australia. It is, for equivalent strength, considerably lighter than former construction and, if made of the same weight, possesses much greater strength. Before its introduction, yearly mileages per locomotive were from 20,000 to 50,000; modern bed-equipped locomotives make from 100,000 to 150,000 miles annually.

The principal maintenance on built-up frames is caused by loose bolts between the side frames and the connecting and attaching parts, especially the front deck, air pump brackets, cylinders, engine truck center pin, guide bearer crosstie and motion work crosstie. Bolts holding the frame and cylinder, and the frame and crosstie, often "work" so fast they have to be renewed one or more times between shoppings and each renewal means that the hole must be reamed. It is a common thing to find that these bolts, which are usually about 1¼ in. diameter when new, have been increased in size in five to seven years, through repeated reamings and renewals, to as much as 2¼ in. diameter.

As the initial spacing is usually as small as possible, this reduction of approximately 1 in. in the bridge between bolt holes is a serious matter and invites, and eventually causes, a crack across the bridge. Although the bolt body may be increased with successive reamings, the room required for wrench clearance for turning the nuts necessitates adhering to the original thread and nut size, thus resulting in a bolt with two diameters. This aggravates the difficulty.

A recent survey of the comparative frame and cylinder maintenance costs, by a road having several groups of the same class of locomotive, showed that the first lot of 50 with built-up frames and separate cylinders had a great deal less availability than subsequent lots equipped with beds. The miles per month decreased with the age of the locomotives with the built-up frames, while the monthly mileage of the comparable bed-equipped power remained fairly constant. All of the bolting difficulties previously mentioned were found to be present in these built-up frames. Hence it was justifiable to replace these built-up frames and cylinders with one-piece beds.



Casting the Bed Frame of a Locomotive Tender Into a Water-Tight Bottom for the Cistern Not Only Increases Its Capacity But Lowers the Center of Gravity and Minimizes Corrosion

This decision was hastened by main frame failures which had followed the welding of crossties and cylinders to the frames, such welding having been done in an effort to relieve the attaching bolts and help keep them tight. These frames, in some instances, had broken adjacent to the welds from thermal strains set up in the high carbon steel due to application of welding temperatures. It was impracticable to normalize these assembled structures on account of the almost certain distortion which would follow.

The development of the one-piece steam locomotive bed was along no "royal road," for it must be recognized that it represented a long step forward. The rules governing design were largely empirical, and it was early found that they could not be applied to the one-piece bed. A new technique had to be developed not only in the art of molding and machining, but all previous ideas on locomotive casting design had to be either discarded or entirely revamped.

Experience on several roads with the earlier design of beds showed that weaknesses developed where calculated stresses seemed to be very low. It was found that thermal strains produced by expansion and contraction of the steam in the cylinders and passages were responsible for most of these difficulties. These studies also indicated that the loose bolts and failures of the cylinders and other parts of the built-up frame construction could be directly traceable to the same source. Ways and means were found, by changes in design, to relieve these stresses in the one-piece bed, and now even a slight service defect in the vicinity of the integral cylinders is a rare occurrence.

Attempts have been made from time to time to improve the construction of the so-called bar or two-rail type of main frame, but none has proved of lasting value. The latest effort is the "flame-cut frame" which consists of a two-rail type of frame cut by a gas flame from a rolled slab. The cast steel frame of this same type has, as a result of improved foundry practice, been brought to such a high degree of efficiency that a failure rarely occurs from direct stress; in fact, the principal difficulties are those caused by loose bolts and inadequate sections at bolted connections. The substitution for a casting of a rolled steel member, no matter how perfect, under such conditions would apparently have little to offer in the way of improved service.

Much attention has also been paid to the design of the driving wheel center. This is a large subject in itself, and since it has been discussed in some detail by Raymond L. Collier in Metal Progress last February, it will only be mentioned here.

The development of the tender for steam locomotives presents another excellent example of the adaptability of steel castings in a most rigorous service. Earlier tenders with two four-wheel trucks carried 4000 or 5000 gallons of water and about six tons of coal. Their frames were made of wood, and the combined cistern and coal bunker were superimposed on these frames. Later, as the water capacities were raised to 6000 or 8000 gallons with correspond-

ing increases in coal, the wooden frames were replaced with rolled steel sections having cast draft housings and pivotal connections for the trucks. In this design sulphur bearing coal and cistern leakage caused rapid corrosion.

In 1907 the first one-piece cast steel tender frame was introduced. It immediately found favor, and its use was rapidly extended, so that in 1917, when the United States Railroad Administration was developing standard locomotives, it was decided, in the interest of economical tender maintenance, to use it in all the standard locomotives. At that time, tender capacities had grown to as high as 12,000 gallons of water and 16 tons of coal.

During the years following the War, an intensive drive was made to increase locomotive availability, efficiency and economy. It was found that larger tenders, operating through the arid Southwest, permitted longer locomotive runs with fewer stops. However, it was found that these larger tanks tended to separate from the frame in a collision and telescope the locomotive cab.

Nevertheless, the demand for still larger tenders continued, and this was accompanied by the urge for still greater safety. Limits of height and width had been reached and increases in length meant, in most cases, longer turntables and engine stalls. With these large tenders, too, it was evident that the center of gravity should be lower. Out of all of this grew the water-bottom tender in which the depth of the tender frame was utilized for additional water capacity. The bottom of the cast steel frame was made a solid pan, and the sides, ends and internal bracing attached to its upper surface. This formation of the tender frame as the cistern base, in addition to effecting a large increase in water capacity, entirely removed the telescopic hazard and substantially lowered the center of gravity. With this modern tender, water capacities have been raised to 25,000 gallons and coal to 36 tons. During the past year, one road wishing to use a large tender and keep within restricted wheel loads, decided to use two eight-wheel trucks, and such tenders are now under construction.

A further improvement in water-bottom tenders is the water-bottom stoker trough. In these coal for the locomotive is conveyed from the tender through crushing elements in the stoker trough to the fire box. Previous practice sacrificed a portion of the volume for a compartment for inspection and maintenance of the stoker. The sides of this compartment formed cistern walls, and the surging of the water against them was always a source of expensive maintenance in very restricted space.

The heavy duty imposed on the built-up trough due to its dual function of conveyor and crusher, and the difficulty of adequately bracing it to the tender, while at the same time permitting the periodic removal without undue complication, made an improved construction imperative. Cast steel has effectively met every one of the requirements.

The cast trough is permanently welded on top the tender frame. The underside of the trough proper is the top of a water compartment and all the surrounding space formerly unused is now a part of the cistern. Seven years of service with no repairs other than replacement of the wear plate in the crusher zone have amply demonstrated its utility. The freedom from corrosion of the cast trough, together with its sturdy construction and the ability to adequately and permanently attach it to the balance of the tender thus provide another very important improvement.

Many Thousands in Service

There are now in service over 25,000 cast steel tender frames and more than 3000 cast steel underframes for freight cars, these latter covering almost every type of car. The largest single lot was for 1500 flat cars built in 1934 by the Pennsylvania Railroad. The cast steel underframe makes the freight car a much stronger unit and almost indestructible even in a wreck. On account of their corrosion resisting qualities, cast steel underframed cars have proven of great value in the transportation of bulk sulphur and coal. There are also several hundred such cars in ore service on the Missabe Range in northern Minnesota.

The use of steel castings in railroad service today is so general that no further historical reference seems necessary. They have in nearly all important applications superseded gray and malleable iron castings, and even forgings except in uses requiring highest resistance to dynamic stresses, such as main and side rods and axles.

There has been considerable discussion as to the physical and chemical characteristics of various cast steels for different railway needs. It would seem logical to determine this question largely on the basis of the use to which the

particular casting is to be put. It must, however, always be borne in mind that every railway vehicle is subject to the hazards of wreck or other emergency conditions. It is important therefore that structures of the size of beds, or tender frames, be made of material that will withstand much shock and at the same time be readily weldable if damaged in accidents without the necessity of subsequent heat treatment. It is equally important that the casting be made of ductile material that will withstand deformation with the least amount of fracture, and when this occurs, it is essential that these can be readily straightened.

For this reason, a low carbon steel similar to Grade "A" in A.S.T.M. specification, A87-36 was selected and the results over long periods have been most satisfactory. As there are many machined surfaces on these large integral castings, heat treatment subsequent to their machining would warp them and impair their usefulness. On the other hand, by proper selection of welding rod and the use of accepted welding technique, damaged portions of these large low carbon steel castings can be repaired with the expectation of permanently successful results. Experience clearly indicates that it is wise, both with lower carbon steels as well as alloys, to sacrifice some degree of tensile strength in order to obtain toughness and weldability. There are of course uses such as driving wheel centers which require a harder steel on account of special requirements such as withstanding axle and crank pin pressure fits. There are also cases where alloys can be economically introduced in order to obtain minimum weight and maximum strength, but these must be considered as special individual cases.

WELDING OF STAINLESS

BY J. C. HOLMBERG

Abstract from The Welding Journal, Oct. 1937, p. 44

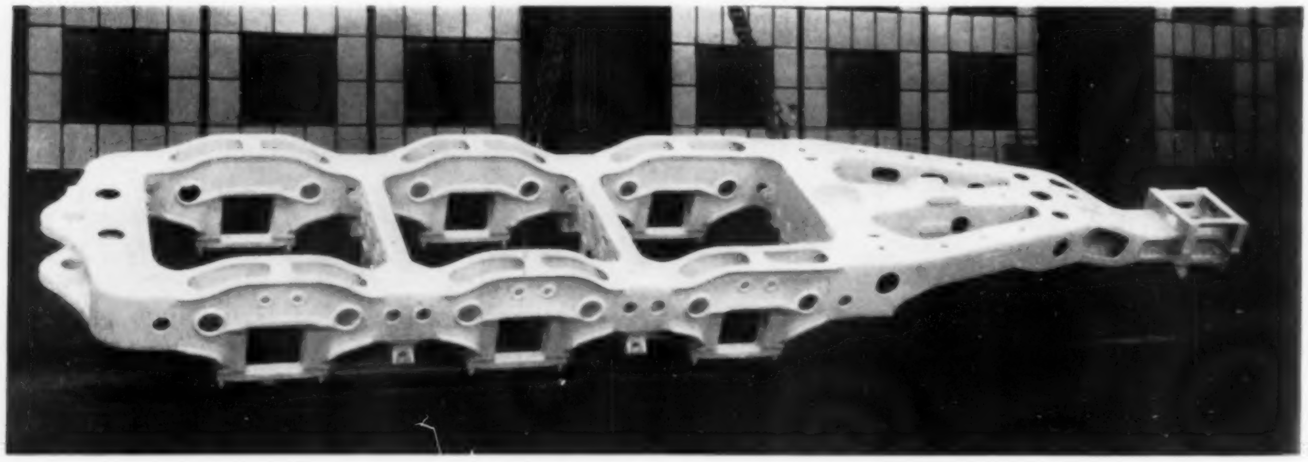
WITH THE GROWTH of popularity of stainless steels has come a corresponding growth in acceptance of welding as a correct method of jointure. Satisfactory performance has encouraged a remarkable expansion, especially in the chemical and food industries, of large and complicated equipment. Struthers Wells-Titusville Corp. has, through a period of years, developed some welding techniques which may have general interest; we early realized that the methods were dissimilar to the welding of heavy steel plate, and therefore equipped a shop for the sole purpose of working alloys.

Preliminary fitting must be quite accurate if a smooth "sanitary polished finish" is to be achieved (as frequently specified for tanks and equipment for the food industry). To secure this, all seams must be flat with no depressions that would not polish clear and clean.

Clad or bi-metal sheets introduce special problems. The joint must have the strength of the steel backing, yet the noble surface must not be contaminated with iron. In the case of nickel-clad steels, so popular for caustic resistance, we assemble and tack the component sections together from the outer (steel) side — then weld the nickel side, using a pure nickel electrode. We then chip out the tacks and complete the welding from the steel side. This produces joints with iron dilution under 5%.

In attaching the necks and other fittings be careful that no steel surfaces are left exposed. Nickel welds at these points must be rather wide and carefully examined for evidence of porosity.

(Continued on page 194)



Single Piece Bed for Pennsylvania Railroad, 1935 Electric Locomotive

Metal ceramics is the apt term used by Dr. Hoyt to denote molded mixtures of metals and non-metals fired at high temperatures. The starting point is powdered material, properly blended. Results include oil-less bearings, electrodes for resistance welders, carbide cutting tools — to mention only the most important ones. Outlines of the manufacturing processes and the resulting properties are given, together with indications of a wider field of utility. Dr. Hoyt is especially well fitted to discuss carbide cutting tools, as he did much work when with the General Electric Co. on the early development of hard carbides

METAL CERAMICS MOLDED FROM POWDER

BY SAMUEL L. HOYT, A. O. SMITH CORP.
Director of Metallurgical Research — Milwaukee, Wis.

A DISCUSSION of powder metallurgy contained in December METAL PROGRESS (page 749) described products which are essentially homogeneous, whether they be pure metals with or without small amounts of non-metallic additions, or alloys of two or more metals. We come now to a branch of powder metallurgy which can be distinguished from the former by the presence of two major phases, though the distinction may not in all cases be very rigid. One of the phases or constituents may be a cement which holds the grains of the major constituent rigidly together. Porosity may play an important part in these products in one way or another, as we shall see.

Perhaps the first bodies of this kind to be made were the copper-tungsten electrodes for spot welding and the porous bronze-graphite bearing materials. The former was made by pressing up a tungsten ingot, sintering it at such a temperature that while considerable consolidation and strengthening were produced, considerable porosity was left in the sintered product. This porosity had also to be of the continuous type. The final step was that of heating the porous bar in a hydrogen furnace in contact with molten copper. The copper was drawn into the pores by capillary attraction and produced a composite bar which was about 40% copper. The tungsten matrix or skeleton gives the body great strength at high temperatures while the copper is present in sufficient amount to give it quite high conductivity. On account of this combination of properties this material has found use as welding electrodes and is able to compete even with copper or copper alloys under many conditions of temperature and pressure.

While the process is simple enough in principle, it is necessary to have all the steps under fine control if uniformity of copper penetration and the physical and electrical properties are to be uniform. Control of both porosity and copper penetration is provided by control of the particle size of the tungsten powder, assuming other conditions to be held uniform.

The second product mentioned above is now known generally as the "oil-less bearing." This is a porous, yet compact, bronze which contains graphite. Its composition is close to 88% Cu, 10% Sn and 2% graphite. It is an excellent bearing and, with the pores filled with oil, it is generously self-lubricating.

Oil-less bearings were first made by mixing

copper and tin oxides with graphite, pressing into shape, and then firing in an atmosphere of hydrogen to reduce the oxides and sinter the bronze powder which formed. This produced a bronze matrix which contained graphite uniformly disseminated and which was somewhat porous, voids amounting to about 35% by volume. Upon treating this body with lubricating oil the oil was sucked up into the pores where it became an ever ready source of lubricant. A small amount of heat or pressure applied to such a bearing drives oil out to the surface, both of which responses are favorable characteristics of a bearing.

Their excellent lubricating properties make them efficient as bearings while their unique capacity for storing oil and supplying it when needed makes them especially valuable for inaccessible places. Probably the closest approach that is made to the oil-less bearing by melting and casting is the well known leaded bronze bearing metal, and it cannot be produced in a porous condition. (Attempts have been made to produce a porous cast alloy by heating to a temperature above the melting point of the eutectic and centrifuging to expel the liquid portion).

The method outlined above has since been modified for commercial use by starting with the two pure metals in powder form, instead of the two oxides.

These bearings were quickly adopted by industry and today they are used in the automotive industries in great quantities. It is understood that this application is responsible for the greatest use of metal powders in metallurgy. The industry is truly on a production basis with automatic machinery for mixing the powders and pressing the parts and controlled atmospheres for sintering them. Great emphasis is placed on the accuracy of dimensions, and ease in fitting them in place in the finished assembly. Further economies result in a freedom from machining costs, except for minor shaping operations, and the practically complete utilization of the raw material.

The competitive method of casting a bronze bearing requires the use of sink heads, risers, or runners, and the parts have to be made somewhat larger than the finished size and hence have to be machined, all of which produces scrap metal. On the other hand the powdered metals cost more to produce than the ingot metals used in melting. More recently iron powder has been substituted for copper in some bearings to secure greater strength (*American Machinist*, May 20, 1936).

One peculiarity showed up in the early experience with this product. While the finished part could be whittled with a pen knife and could be crushed fairly easily, machining it was a practical impossibility. Even a light cut of short duration was sufficient to take the edge off a high speed steel tool. The only plausible explanation for this outstanding characteristic is that the graphite here acts as a powerful abrasive, and this behavior appears to deny the very reason for its addition to the bronze!

Cemented Carbides

We come now to one of the most fascinating products of powder metallurgy, the hard cemented carbides.

It has been known for years that many of the metallic compounds are excessively hard and attempts have been made frequently to utilize this outstanding property. By an interesting coincidence it was at the lamp factories which must use diamond dies for drawing tungsten wire that this work became of great importance, though I do not wish to infer that no others participated in this work on the hard compounds.

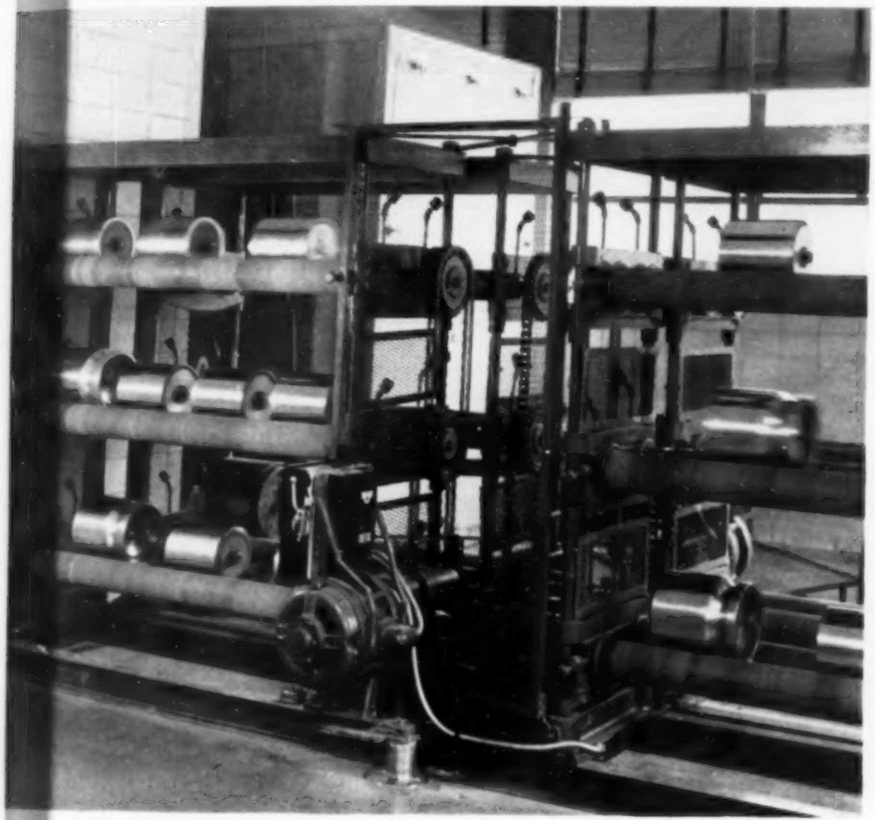
It was first attempted to make dies of fused tungsten carbide and while this work does not concern us here, a very interesting metallographic system was discovered in which the structural changes during solidification of the highly carburized metal limited the product to the eutectic mixture of the two carbides, W_2C and WC. It was also found that by controlling the cooling conditions a reasonably fine grained mixture of these two carbides could be secured which gave serviceable dies. This, and other experience, drew interest to tungsten carbide on account of its extreme hardness.

A step of major significance was taken when, instead of fusing tungsten carbide, tungsten metal powder was converted into the carbide WC and a small amount of cobalt was added to cement the carbide particles into a body of great hardness and great compressive strength. This was the first of the cemented carbides which are now so extensively used for dies, tools, and other purposes which utilize this outstanding combination of properties.

The tungsten powder is the same as is used for the manufacture of lamp filaments. It is mixed intimately with fine carbon and fired at about 1500° C. (2750° F.) to convert it into WC.

(Of course the carbide W_2C could be made by this method if desired but it does not have as valuable characteristics as WC. The same is not true of the fusion process, for WC cannot be made to solidify in the pure state directly from the melt.)

After the carburizing treatment the combined carbon content is about 6.1% with no free carbon. Under certain circumstances a certain amount of free carbon can be tolerated but there appears to be no advantage in having it. The cobalt powder is prepared by hydrogen reduction of powdered cobalt oxide, the latter having been first properly purified. There is some advantage in using fine cobalt for mixing with the carbide and hence it is reduced at a fairly low temperature. If the powder is too fine to expose to the oxidizing influence of the air it can be sealed off under carbon dioxide.



Mixing of Powdered Tungsten Carbide With Cobalt — and Often Some Binder Like Paraffin — Is Done in Small "Ball Mills." These contain steel balls that rub the powders together, smearing each particle of carbide with the ductile binder. Photographs were taken in the new plant of Firth-Sterling Steel Co. for making "Firthite Firthalloy" sintered carbide tools

Having produced the two powders of tungsten carbide and cobalt they are mixed in proportions running from 3 to 13% of cobalt by weight. This is done in a steel ball mill with steel balls — for one reason to produce a cobalt smear on each carbide particle. Before milling, the two mixed powders could be separated with a magnet but, after milling, the entire mass responds to a magnet.

Pressing and sintering are carried out in about the same way that was described for tungsten in the former article except that the sintering temperatures are lower. On the other hand some powders press up less readily into sound bars of uniform texture than others and if a material is otherwise of good quality the mixture may be treated with a binding material like paraffin dissolved in kerosene. Upon driving off the kerosene the paraffin coats the particles and improves the action of the powder during pressing.

Usually the pressed bar is presintered at a low temperature which strengthens it sufficiently for preliminary shaping; in this condition the bars can be readily cut and approximately the correct final shape given to each part. The final sintering is done at some temperature in the range from 1350 to 1500° C. (2450 to 2750° F.), being higher for smaller amounts of cobalt. This converts the mass into a permanently hard and strong condition which can then be shaped only by such operations as grinding, lapping, and polishing with the hardest abrasives.

It has been found that good results can be secured by pressing the carbide-cobalt mixture at about the same temperature as that used for final sintering. Furthermore it has also been found that with this method the three powders of tungsten, cobalt and carbon can be pressed hot directly into the final product. Here the cobalt acts to accelerate the combination of tungsten and carbon to produce WC.

This process has been of some use in reclaiming fragments of the fully sintered product, but it is used principally because with it fine diamond chips can be successfully incorporated into the cemented carbide. This diamond-impregnated material serves as a suitable substitute for massive diamond and has advantages over the common diamond for such things as wheel dressers. The superhard matrix of the carbide does not readily wear away and hence

maintains adequate support for the active diamond particles.

The cementing action of cobalt may be described as follows: As the mixture is heated to the full sintering temperature the cobalt dissolves a certain amount of the finer carbide and forms a liquid phase. This liquid wets the carbide particles and draws them together, while upon cooling the cobalt phase becomes a solid cement. It is so attenuated that it acts like a thin film rather than like the soft massive cobalt. Apparently when the cobalt exceeds about 20% by weight the effect of massive cobalt enters strongly and the body loses the great hardness of the standard product.

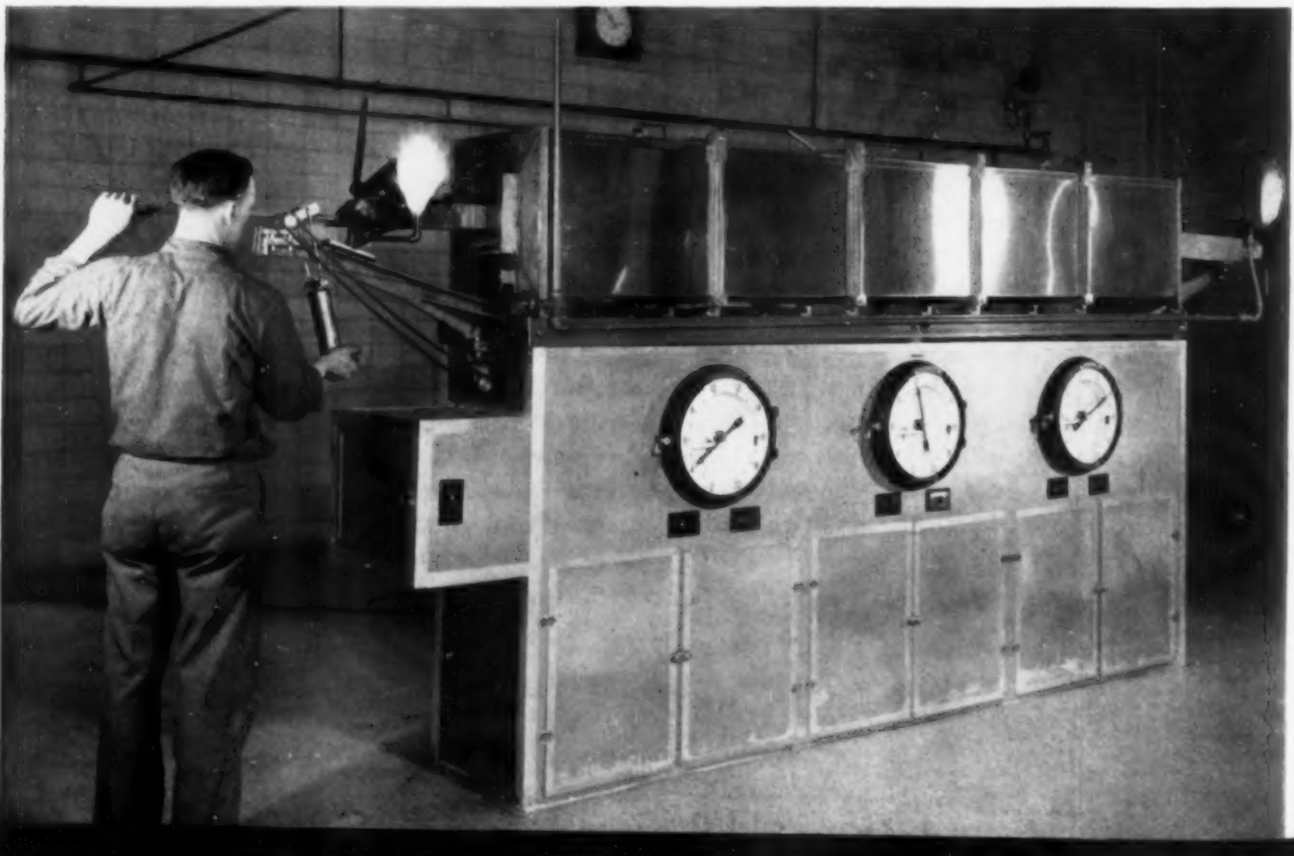
Iron and nickel can be used to cement tungsten carbide but neither is as satisfactory. Some metallographical reasons for this difference have been recently advanced by Takeda in the Honda Anniversary Volume of *Science Reports*, Tohoku Imperial University, p. 864.

Manufacture of dies and tools from the cemented carbide does not fall within the scope of the present discussion but we may digress long enough for a few comments on the methods developed to process this material. Some of the non-metallic carbides are even harder than tungsten carbide and can be used to grind and lap them, while diamond dust is also used for the more exacting requirements. With the equipment and technique available, the cemented carbides are regularly worked to as close tolerances as any that are used for the softer metals. As an example, a ring gage is made so accurately that the plug can be prevented from entering by squeezing the ring in the fingers. Hence the initial dimensions in the unstressed condition must have been extremely accurate.

The success of the cemented tungsten carbides attracted considerable attention, particularly along the lines of developing improvements or at least substitutes. This resulted in a great amount of work as will be clear from a reading of the book by K. Becker on the "Hochschmelzende Hartstoffe und ihre technische Anwendung." The whole class of hard metals or compounds has been examined including nitrides, carbides, silicides, borides, phosphides, and double compounds, and even solid solutions of the hard compounds have been disclosed. While we may assume readily enough that many of these have interesting properties, additions to the tungsten carbide which have met the requirements imposed by commercial usage have so far been limited to the tantalum carbide TaC, and the titanium carbide TiC.

Of these two the former is the more important and has the unique combination of great hardness and low coefficient of friction or seizing against steel. When machining steel the tungsten carbide tools are worn by the chip which passes over the top cutting face, while the tantalum carbide tools are much less affected by this action. The technique used for the production of tantalum carbide is much the same as that used for tungsten carbide except for the difference already noted for tantalum — it must be protected against hydrogen and nitrogen when heated though here there is no harm from heating in carburizing atmospheres.

Powders Are First Pressed Into Billets and Sintered at Low Temperatures Under Hydrogen Into a Material That Is Easily Cut Into Tool Nibs and Useful Shapes. These are then sintered at high temperature



The Products of Powder Metallurgy

At the beginning of the first article it was pointed out that the survival of powder metallurgy must depend on its accomplishing something not possible with — or not as easily done by — the older or more conventional arts. Stated in another way, the products of powder metallurgy must have unusual and outstanding properties. Let us now review some of the principal characteristics of the more common products.

We have learned that tungsten makes the best known lamp filament. This is primarily due to the combination of a low vapor pressure and a high melting point which permits operation at high temperatures. A second advantage of the high melting point is the possibility of sintering the pressed ingots at temperatures of 3000° C. to secure good workability, though it might be argued some day that such a requirement simply reflects the inherent properties of a material that has both a high melting point and a low vapor pressure.

Actually tungsten is the most refractory of all the metallic elements. It may not be as well known that tungsten is also our strongest element when drawn into fine wire less than 0.001 in. in diameter, and that it has the highest modulus of elasticity. The figures are 600,000 psi. and 60,000,000 psi. respectively. It is also the strongest metal at high temperatures. Contrary to the common rule tungsten is most ductile (at room temperature) when in the hard drawn and fibrous condition. Tungsten is the heaviest of the common metals, with a density of 19.3 g. per cc. Though not hard in the usual sense, with a Brinell hardness number of but little over 200, it is practically non-machinable. Tungsten also has the lowest coefficient of thermal expansion of the metals. This is the metal which provides our best lamp filament, the best X-ray tube target, the best contacts for automotive ignition systems, and also enters into other products of powder metallurgy.

Another element, which is now used because its production can be mastered by the processes of powder metallurgy, is tantalum. This metal is both strong and malleable and is outstanding in the chemical field on account of its superior resistance to many types of corrosive attack. If we could evaluate this characteristic by some simple figure we should undoubtedly see that it too was unique. Tantalum also finds ready use in the construction of vacuum tubes though it is the chemical field that gives it its chief claim to utility. The marked malleability of tantalum is surprising in view of the brittle character of the somewhat similar metals tungsten, molybdenum and chromium, for all four of these metals have the body-centered cubic arrangement. This behavior of tantalum would appear to warrant more attention on the part of our scientific investigators.

Molybdenum is the third element produced by powder metallurgy commonly used today but its properties do not fit it for any outstanding use in the pure state. Its cost in the wrought form is less than that of tungsten and this factor is chiefly responsible for most of its applications in the lamp and vacuum tube industry.

Coming to the metal ceramics we meet additional superlatives. At the head of the list come the cemented carbides, principally tungsten and tantalum carbides. They have the highest cutting efficiency of any metal or alloy, whether measured in terms of the Taylor constant or

Tips, Which Form the Cutting Edges, Are Fastened in Notches in Steel Shanks by Copper "Brazing." Snug Assemblies are heated to 2050° F. in strongly reducing atmosphere and the copper penetrates the joint

determined in the production shop. They are also capable of machining the hardest substances that are commonly machined. Though the diamond is still harder, its inherent tendency to chip limits its use to light finishing or burnishing cuts.

While it cannot be said that cemented carbide is harder than the chief constituent, we may say that it is the hardest metallic body which still possesses the strength of steel. In some cases this hardness amounts to about 2500 kg. per sq.mm. as a measure of the resistance to the penetration of a diamond point. Our hardest steel runs just above 1000 on the same scale. These same materials retain their hardness at elevated temperatures to a greater degree than do other metals.

The transverse modulus of rupture, which is a measure of the strength, runs from 200,000 to 300,000 psi. and over, as compared to steel which may run over 400,000 psi. The cemented tungsten carbide also has the greatest compressive strength of any material, or from about 600,000 psi. up to nearly 800,000 psi., and Dr. Jeffries has written me that this property has enabled the material actually to open up a new field in the study of high pressures. This is about double the compressive strength of hard steel. Furthermore, the carbide of tantalum and its associate the carbide of columbium have the highest melting points of any substance with the possible exception of the element carbon. Actually their melting points lie above 4000° C. (7250° F.).

Welding electrodes for heavy duty made of copper-tungsten again owe their use to superior properties — an outstanding combination of high electrical conductivity and high crushing strength at elevated temperatures. The porous bearings also provide a rather unusual combination of bearing properties and self-lubrication that cannot be duplicated by the more conventional metallurgical arts.

This brief review establishes the significant fact that powder metallurgy occupies its position on account of its ability to produce materials with outstanding properties, and not because the processes are inherently cheap or simple in comparison to other arts. Some of the characteristics of powder metallurgy are so effectual in reducing production costs that we may some day find that the new art is capable of competing on equal terms with the older metallurgical arts for the production of the same part.

FRICTION AND LUBRICATION

A THREE-DAY conference on "Lubrication and Lubricants" was recently held in London under the auspices of the Institution of Mechanical Engineers. From a serial report in *The Engineer*, starting with the issue for Oct. 15, 1937, and editorial comment, the following brief notes are taken:

Since the principal function of lubrication is to reduce friction, an inquiry into the true nature of the latter is in order. Properly known, it would harmonize much diversity of opinion about lubrication. A tentative theory is that friction is molecular in origin. It is suggested that when two bodies are placed in contact, those areas of the surfaces lying within the range of molecule-forming forces unite and form a number of little bridges between the two bodies. When motion occurs, the bridges are broken with a generation of heat. When the bridges are broken, fresh areas come into contact and form new bridges. According to this interpretation, we are to suppose that the areas within the molecular range are constantly changing their position on the surfaces of the bodies, and the true nature of a lubricant is to reduce the number of areas lying within the molecular range.

Some experiments to substantiate these ideas used two bodies of different metals as the junction of a thermocouple, and it was found that relative motions created very high temperatures. With lead and mild steel, local temperatures equaling the melting point of lead were recorded. With other metals, temperatures of 1800° F. were recorded. Temperature increased with speed of sliding and with load on the bodies; high — although not quite so high — temperatures were recorded with water lubrication. Force required to maintain sliding motion is not constant but fluctuates violently. There is an alternate sticking and slipping with resultant high temperatures. The stick is for a short time and the high temperature is dissipated very rapidly.

The mechanical theory concerning the actions in slow speed journal and thrust bearings is well worked out and understood by designers. However, each installation is a problem in itself. The maintenance of the oil film is often impossible, the bearing temperature or the rate of heat transfer may be the primary factor. Another consideration which compels the bearing designer to deviate from theory is the impossibility of obtaining geometrical perfection under practical conditions. Bearing propor-

(Continued on page 206)

While some use has been made of alloy steels by American railroads prior to the advent of the light weight streamliners, the usual custom was to avoid materials whose utility depended on heat treatment, because of the inability of most maintenance departments to recognize and repair such parts properly. Important recent developments include light weight trucks for freight cars, made of normalized nickel-manganese steel. Use has developed from 50 experimental cars in 1935 to 2650 cars in 1936 and over 5000 cars in 1937. Mild nickel or nickel-vanadium steel is favored for engines and passenger cars

NICKEL STEEL CASTINGS IN RAILROAD ROLLING STOCK

BY T. N. ARMSTRONG, INTERNATIONAL NICKEL CO.
Development and Research Division, New York City

AMERICAN railroads have long recognized the advantages of alloy steel and certain roads had standardized on alloy for such castings as locomotive frames, driving wheel centers, and crossheads, but it was not until the development of light weight streamlined trains that serious consideration was given to alloy steel castings in car construction. Truck frames were specified for these cars of cast alloy steel, as it was desired to lighten the weight of the trucks but at the same time it was essential that the truck frames, lightened by change of design and by reducing the section, possess both high elastic properties and toughness.

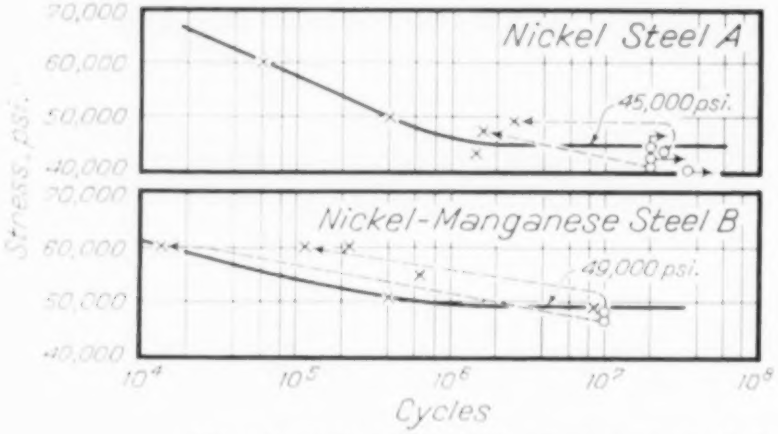
At about the time streamlined trains began operating, an equally interesting but much less publicized development was the reduction of dead weight in freight cars, accomplished by using rolled, low alloy, high tensile steel for car bodies and replacing carbon steel side frames, bolsters, yokes and other cast parts with alloy steel castings.

In these developments cast nickel steels have played an important part. Some of the compositions have been used extensively in other fields; others are new and were developed to meet special conditions resulting from radical changes in design of equipment and from changes in operating conditions.

Locomotive Castings

High ductility is one of the primary requisites for locomotive frame castings; high tensile strength, while desirable, is not as essential as toughness. High strength permits reduction in size of sections but the limit in locomotive frames depends more upon rigidity requirements than upon the inability to obtain high tensile properties. The toughness of the cast nickel steels, together with high fatigue strength and excellent ductility, has been the basis of their selection.

A composition that has met with general approval contains a maximum of 0.20% carbon and a minimum of 2% nickel. After a double normalizing and tempering treatment this steel possesses high ductility, good tensile and fatigue strength, and elastic and impact properties much superior to carbon steel of equivalent strength. The heat treatment consists of air cooling from the range 1700 to 1850° F., air



Stress-Cycle Curves Indicating Endurance Limit of Cast and Heat Treated Steels Noted as "A" and "B" in the Table Below. Points connected by light lines indicate sample unbroken at lower stress is loaded more heavily and then breaks after indicated number of additional alternations

cooling from 1500 to 1550° F., and drawing at 1000 to 1200° F. This steel also possesses the property of retaining its toughness at low temperatures, which contributes to uninterrupted service on railroads where winter temperatures are often below zero.

A second composition used for locomotive frame castings is a nickel-vanadium steel with a maximum of 0.25% carbon, and a minimum of 1½% nickel and 0.10% vanadium. After a double normalizing and drawing from the same ranges this steel possesses properties similar to those of the low carbon, 2% nickel steel, as can be seen by the table below.

As the carbon content in both the nickel and nickel-vanadium alloys is limited to a comparatively low figure, these steels do not air harden and therefore may readily be welded in place and without a subsequent strain relief anneal. Before arc welding had been accepted as an approved method for joining steel parts the usual method for repairing broken frames, which at the time were of higher carbon content, was to use the thermit process. These welds would generally last the life of the frame but it was not unusual for another break to occur next to the weld. Lowering the carbon content and building up strength with alloys has done much to prevent broken frames, and on the rare occasions that breaks do occur they are fusion-welded without damage to adjacent sections.

Design of locomotive frame castings has undergone several radical changes within the last ten years. The article in this issue by Mr. Sheehan shows that practically all large locomotive frames are cast in one piece with the cylin-

Chemical Composition				Yield Strength	Tensile Strength	Elongation	Reduction of Area	Izod Impact
Carbon	Manganese	Nickel	Vanadium					
Low Carbon, 2% Nickel Steel; Double Normalized and Drawn								
0.18	0.93	2.20		53,300	84,000	30.0	61.0	59
0.18	0.85	2.26	(Steel A)	51,500	81,000	29.0	55.5	62
0.19	0.81	2.20		50,000	80,500	28.0	59.0	56
0.17	0.82	2.18		50,800	80,200	30.5	62.5	64
0.17	0.84	2.10		51,000	79,000	32.5	62.5	55
Low Carbon, Nickel-Vanadium Steel; Double Normalized and Drawn								
0.18	0.62	1.44	0.09	58,500	78,500	26.0	47	
0.19	0.64	1.62	0.10	57,000	83,500	27.0	52	
0.20	0.73	1.60	0.08	64,006	84,000	30.0	63	
0.23	0.60	1.54	0.11	60,000	81,000	29.0	54	
0.25	0.62	1.45	0.10	61,000	80,000	28.5	55	
Medium Carbon, Nickel-Vanadium Steel, Double Normalized and Drawn								
0.30	0.81	1.52	0.11	66,200	96,000	27.5	55.0	56
0.28	0.89	1.66	0.10	65,400	95,000	28.5	57.5	60
0.26	0.97	1.54	0.11	60,500	90,000	25.5	51.0	47
0.28	0.91	1.62	0.12	64,000	94,000	27.0	55.0	57
0.32	0.97	1.60	0.11	70,500	96,800	28.0	60.0	59
Nickel-Manganese Steel, Normalized and Drawn								
0.27	1.48	1.43		62,800	91,400	28.5	63.5	45
0.31	1.60	1.41		68,400	101,700	26.5	59.5	65
0.28	1.62	1.43		69,800	96,500	27.0	57.0	63
0.29	1.44	1.57	(Steel B)	65,400	94,500	28.0	55.0	..
0.27	1.41	1.40		61,000	99,200	24.5	57.5	41

ders integral. These one-piece beds are proving more satisfactory than any other type.

Low carbon steels do not possess sufficient strength for locomotive castings that are subjected both to wear and stress of high magnitude. When higher strength and hardness are desired nickel-vanadium or 2% nickel, each with a carbon range of 0.25 to 0.35%, is often specified. Also it is not unusual to raise the manganese to approximately 1%. Heat treatment is as before noted. These alloys are used principally for crossheads, links, and occasional wheel centers. There is one disadvantage common to all the higher carbon steels — that special technique is required to prevent cracking when the castings are repaired by welding, and they must be subjected to a stress relief anneal.

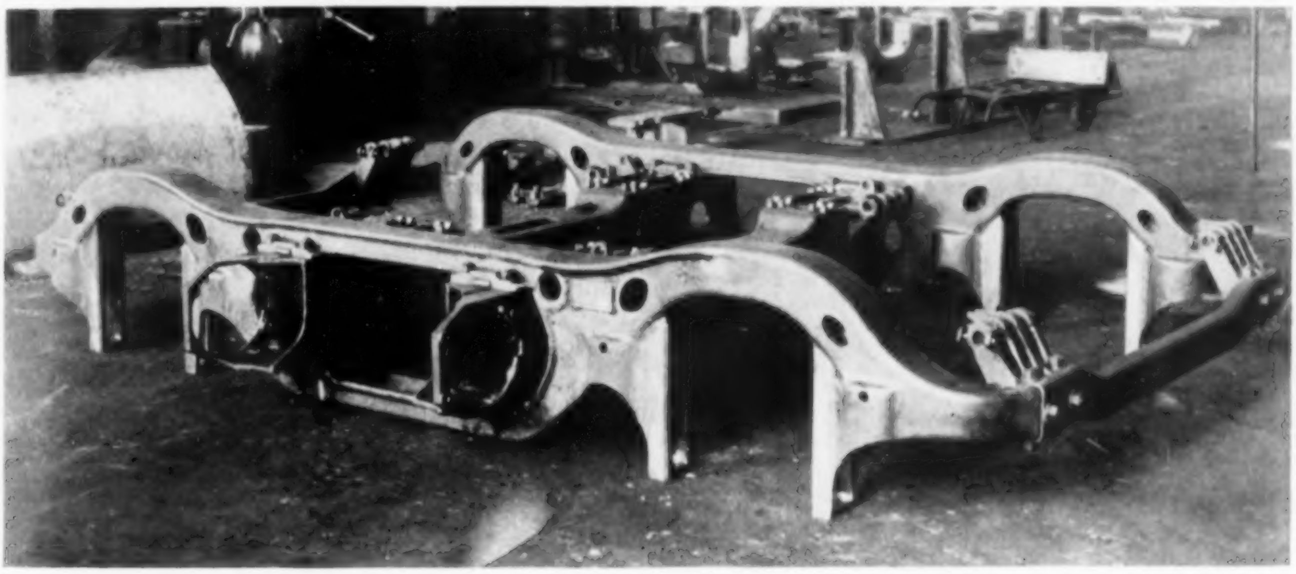
It is not impossible to obtain a high strength steel that has good welding characteristics, as this combination of properties may be secured by using a composition containing very low carbon and comparatively high alloy. However, the high alloy content not only increases the cost of the steel beyond the limit that the consumer is willing to pay but very low carbon content increases the difficulty of producing sound castings, a factor that will also lead to higher costs.

As in the case of locomotive frames, passenger car truck frames fail not by wear but by impact or by fatigue resulting from repeated stresses of lesser magnitude. By lowering the carbon content and building up strength with alloying elements, both fatigue strength and resistance to impact have been improved to such an extent that sections have been lightened without decreasing the safety factor.

The same two alloys which have been popular for locomotive frames have proven to be equally as satisfactory in frames for passenger car trucks.

Freight car castings with but few exceptions are of entirely different design from those used in passenger cars. Castings for the two types of service differ somewhat in properties due to these differences in design and, to a certain degree, operating conditions.

The American Association of Railroads has tentatively adopted a specification for high tensile (light weight) freight car castings that conforms to A.S.T.M. Specification A148-36, Class B, Grade 2, which requires tensile strength of 90,000 psi., yield point of 60,000 psi., 22.0% elongation and 45.0% reduction of area. On casual examination this does not appear to be a particularly difficult specification to meet, but when it is realized that most of the railroad equipment foundries have confined their activities to mass production of carbon steel castings and that heat treating and handling equipment in these shops was installed without contemplating the treatment of alloy steel, the physical requirements do present some difficulties. These foundries, in spite of their handicaps, have produced excellent high tensile castings.



Truck Frame for Union Pacific Streamliner, Light in Weight but Amply Safe, Made of Nickel-Vanadium Steel, Cast and Heat Treated

The most popular alloy for freight car castings is one containing approximately 0.30% carbon, 1.50% manganese, and 1.40% nickel. One advantage of a nickel-manganese steel is that the analysis is easier to control than in a composition depending upon two oxidizable alloys. Nickel also acts somewhat as a stabilizer, as it permits a rather wide manganese range; by adjusting the drawing temperature within the range of 950 to 1200° F. to suit the analysis, variations in composition may be compensated. Such castings require a minimum of handling during treatment as the composition possesses sufficient "kick" to permit air cooling on the car, if a car-type treating furnace is employed. Treatment consists of a single normalize at 1500 to 1550° F. and a draw, whereupon this steel possesses mechanical properties considerably above the requirements. Fatigue strength of approximately 50% of the tensile is also a characteristic, as well as high resilience, although this property will vary somewhat with deoxidation practice, and will suffer at the expense of high strength if the drawing temperature is on the low side.

General Trend

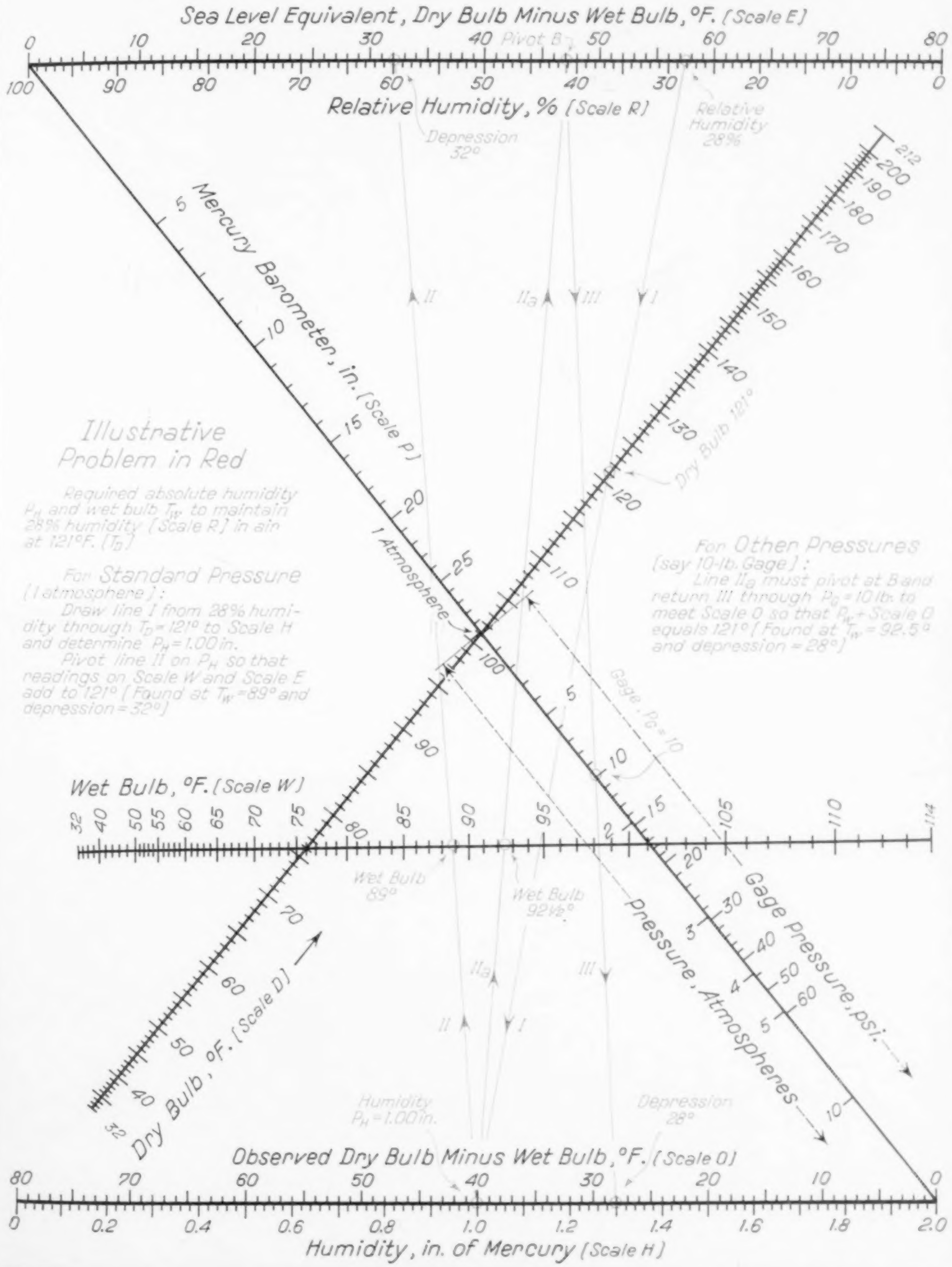
It is difficult to determine to just what extent alloy castings will be used by the railroads in the future. Alloy castings for locomotives are no longer on trial as they have been in service a sufficient length of time to demonstrate their superiority for certain applications. The freight car development is by far the most important from the standpoint of tonnage, and although there are about 7000 freight cars in service equipped in 1936 and 1937 entirely or in part with light weight castings, not including 900 cars built for South American railroads, general acceptance will depend upon the manner in which these cars perform during the next several years and whether advantages resulting from reduction in dead weight will more than compensate the higher initial cost. It is evident that light weight passenger equipment, on the other hand, is here to stay.

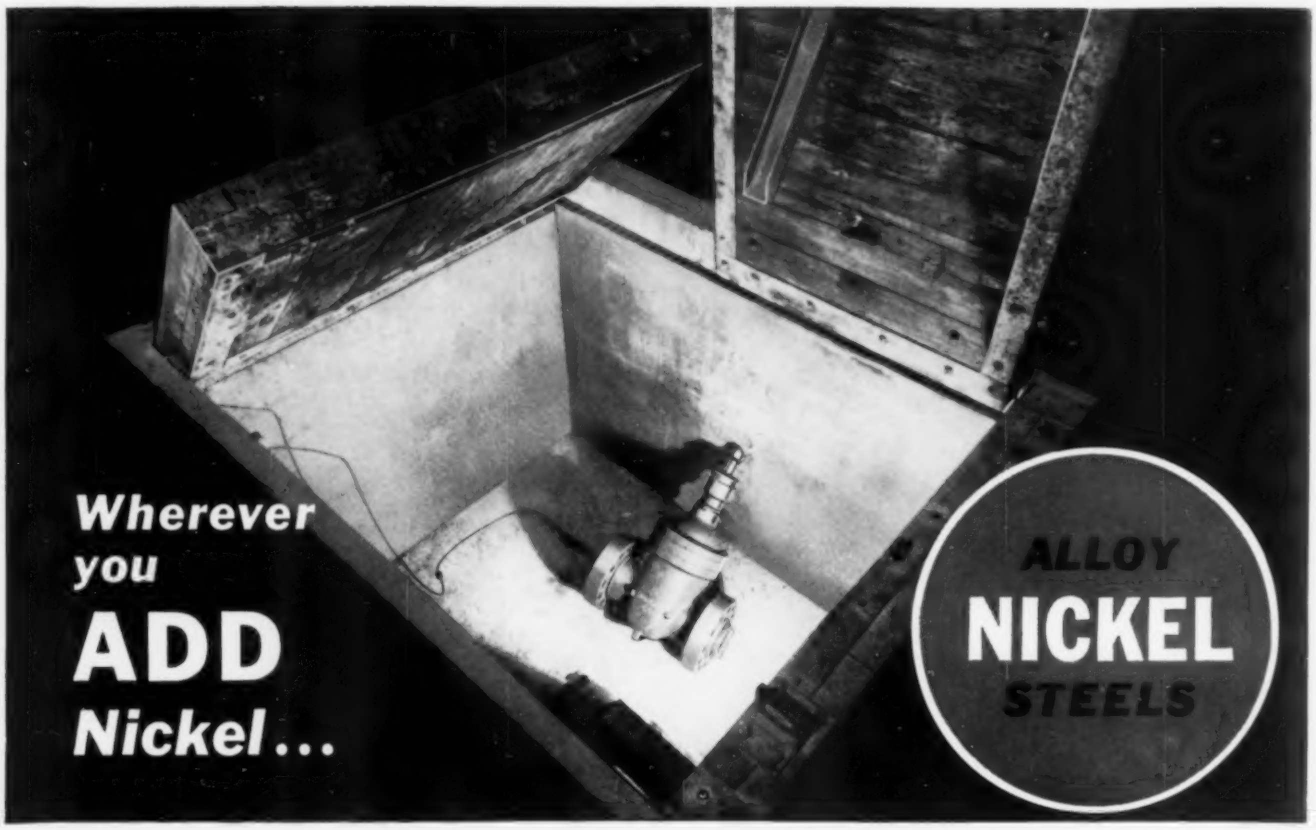
Because of these facts it appears safe to predict that in the not-so-distant future the railroad industry will be one of the largest consumers of alloy steel castings.

Weight is Saved in Modern Streamliners in Three Principal Directions: A. Internal Combustion Engines; B. Stainless Steel Superstructure; C. Alloy Steel Trucks and Wheels

Psychrometric Chart, High Range

By Donald B. Brooks; National Bureau of Standards. Publication M-146

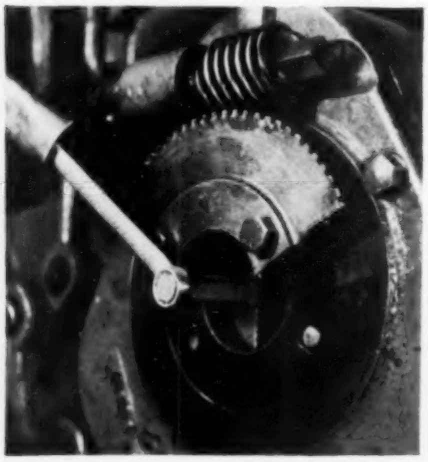




...you quickly SUBTRACT from up-keep costs

Resting in the concrete "destruction" pit pictured above is a high-pressure valve of cast Nickel alloy steel. This is where the Hughes Tool Company of Houston, Texas, tests the strength capacity of valves that are used in the petroleum industry. This firm made its first 10,000 p.s.i. valve over a year ago and the metal selected for the job was cast Nickel alloy steel. The high pressure 10,000 p.s.i. valve illustrated held up to 28,500 p.s.i., nearly three times its specified capacity, in this "destruction" test.

• • •



Here is a story with a tinge of David and Goliath. A tiny wrench doing battle with a torsion machine to determine the load the former will bear before deformation. Note the steel rod which the wrench is gripping. When bolts were used instead of the rod, the heads were twisted off without the slightest effect on the wrench. Note also that this particular wrench is labeled "Nickel molybdenum" steel—the reason for its herculean strength.

Topsy-turvy, this picture showing a man suspended from a highly magnetized pulley merely through the attraction of the nails in his shoes. Up-keep costs are usually revolutionized whenever Nickel alloy steel parts are used. High costs come down because Nickel imparts added strength and toughness—greater resistance to breakage and wear. In this case it's the Nickel steel shaft running through the magnetized pulley that acts as the watchdog of the treasury. Destined to go into magnetic separator equipment made by Dings of Milwaukee, this shaft had to be of small diameter, yet capable of carrying unusually heavy loads. Nickel steel won the job because of its superior strength—in this particular instance 200,000 p.s.i. Our engineers will be glad to consult with you and to point out the many ways in which the Nickel alloy steels will save you money.

THE INTERNATIONAL NICKEL COMPANY, INC., NEW YORK, N. Y.

LETTERS FROM

HOME AND ABROAD

Austenitic Welding Rods For Self-Hardening Steels

Paris, France

To the Editor of Metal Progress:

A feature of both arc and oxy-acetylene fusion welding, which is lately receiving considerable attention, is the use of austenitic steels for electrodes or welding rods, particularly the nickel-chromium austenites such as 18-8 steel.

The remarkable fact about the use of these austenites for welding rod is that they can weld not only the austenitic steels, which is natural, but also high strength, pearlitic or even martensitic steels formerly considered unweldable.

For the nickel or nickel-chromium steels, such as the stainless 18-8, welding rod of the same analysis as the base metal can be used and will make a weld which is chemically and micrographically sound. However, care must be taken to avoid the possibility of future trouble caused by precipitation of high chromium carbides. Thermo-magnetic analysis of this secondary segregation (as described by Chevenard and Portevin) shows that complete local "de-chromization" of nickel-chromium austenites may be caused by the formation of these carbides with resulting bad effect on corrosion resistance.

In welding the unstable austenitic manganese steels (12% Mn, 1% C) the investigations made by the writer and Mr. Sérérian show that stable, high nickel austenites must be chosen for welding rods or electrodes in order to secure a homogeneous weld structure and uniform hardness. These properties cannot be secured by welding with the unstable austenites, particularly in the base metal, even though the joint is chemically sound.

In welding the non-austenitic steels with an austenitic rod or electrode an intermediate hard and brittle martensitic zone is formed which must be corrected in the following ways for the different types of steel:

For pearlitic or sorbitic high strength steels (tensile strength 85,000 psi. and over) nickel-chromium steels of high nickel content (12 to 15% and 22 to 25%) can be used to stabilize the austenite, and thus, as shown by Mr. Waché, reduce to a minimum the martensitic zone formed by diffusion with the base metal, especially at the edge of the chamfer. The 18-8 steels, while they would be more attractive from the standpoint of cost and strength, are too close to the austenitic frontier to act in this way.

The austenitic steels are used in a different manner for welding high strength steels of the nickel-chromium varieties of self-hardening and carburizing steels. Advantage is taken here of the low thermal conductivity and non-hardening properties of this material to prevent brittleness of welds in self-hardening steels without having recourse to a heat treatment *after* welding — a matter always costly and frequently very difficult to carry out.

The self-hardening nickel-chromium steels and their Ni-Cr-Mo-V derivatives are not weldable with rod or electrode of identical composition, that is to say, if a chemically homogeneous weld is to be made. An austenitic steel of the 18-8 Cr-Ni type should again be used.

After deposition, however, a hardened zone is found in the base metal close to the joint, which increases the brittleness of the joint so that under shock, as by a gun shot for instance, the joint may fail. This fracture sometimes takes the appearance of scale on carburized parts. This hardened zone may be determined

by macrographic inspection, which also indicates the thickness of metal so transformed by the welding heat.

All the tests undertaken have shown brittleness after welding because the base metal is locally hardened where the welding bead is deposited. Furthermore, it is often impossible either because of large dimension or unwieldy shape to submit the welded whole to a restorative heat treatment.

On the basis that it would be possible to avoid brittleness in the metal underlying the weld by protecting the transition zone against the effect of the high welding temperature by means of a protective coating such as a non-conducting, non-hardening layer of austenite, Mr. Boutté developed the following procedure:

1. A non-hardening austenitic metal such as 18-8 is first deposited on the surfaces of the chamfers to a depth slightly greater than the thickness of base metal which would be transformed by the welding heat.

2. The parts so treated are annealed to eliminate the brittle zone, and if necessary, they can be hardened and tempered to give the desired mechanical properties.

3. The parts are then assembled and the joints welded, using austenitic electrodes or rods (18-8 or some other composition with Ni, Mn, Ni-Mn, Ni-Cr), the weld being made entirely upon the deposited coating, thus avoiding the necessity of again heat treating the base metal.

Macrographic examination then shows that no martensitic zone surrounds the part that was melted (since it was transformed by the heat treatment before welding and does not re-form), and the welded assembly is not brittle under either static bending or impact tests. Even armor plate assembled by welding in this way can successfully withstand the acceptance tests; likewise high carbon steels, self-hardening steels and even carburized steels.

Such results indicate the importance of the researches undertaken at the Institute of Autogenous Welding in Paris (Ecole Supérieure de Soudure Autogène) and the significance of this method of welding by means of austenitic steels, particularly the nickel austenites.

The essential characteristics of austenite — namely, freedom from brittleness and good ductility, a highly hardened condition unsusceptible to further hardening, and low thermal conductivity — are thus put to good use.

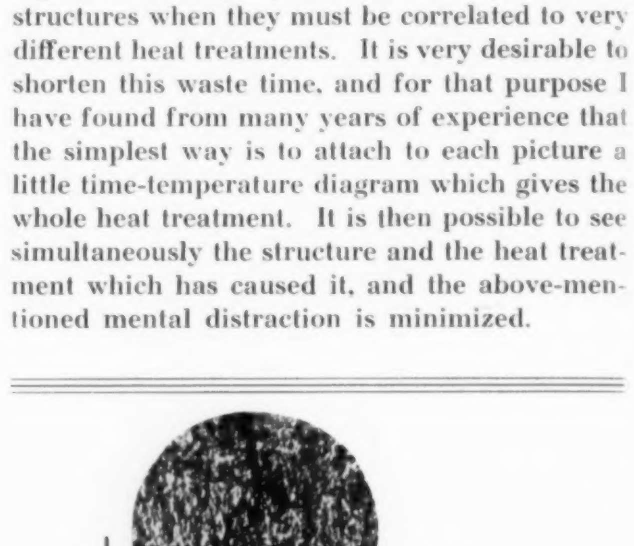
ALBERT PORTEVIN
Professor
Ecole Supérieure de Soudure Autogène

TIME-TEMPERATURE DIAGRAMS TO INDICATE THERMAL HISTORY OF SPECIMENS

LEOBEN, AUSTRIA

To the Editor of METAL PROGRESS:

It is a troublesome matter to go through a report containing a great number of pictures of structures when they must be correlated to very different heat treatments. It is very desirable to shorten this waste time, and for that purpose I have found from many years of experience that the simplest way is to attach to each picture a little time-temperature diagram which gives the whole heat treatment. It is then possible to see simultaneously the structure and the heat treatment which has caused it, and the above-mentioned mental distraction is minimized.



Micro of Structure of Patented Steel Wire, Magnified 1000 Times, and Time-Temperature Diagram of Heat Treatment Undergone by the Sample

In order to make these diagrams as simple as possible, easy to read and not too extended (so that no difficulties in printing may arise) a number of conventional signs may be adopted. The ones I have used are given below, and they have already proved their utility. An example is also given of the following heat treatment: Heat from room temperature to 850° C. in 2.5 hr. (about 5° per min.), hold at that temperature for 12 hr., rapidly heat to 950° C., hold at that temperature 30 min. (Until this moment all treatments are done in a protective gas to avoid oxidation.) Quench from 950° in a lead bath at 380° C., where the piece is held 10 min. Finally cool down in a compressed air blast to room

temperature in about 4 min. (average velocity of cooling 80° per min.).

As shown by the sketch, slow heating is shown by an inclined line upwards and rapid heating by a vertical line. Quenching is indicated by a vertical line downward, and slower coolings by an inclined line downward to the right. Stays at plotted temperatures are represented by horizontal lines; full lines may represent hours, dotted lines minutes (or abbreviations used after the numerals, which conserve the space necessary were they plotted to scale).

If a more precise definition of the rate of heating or cooling is to be given, a number at the left of the respective line will indicate the degrees change per minute. Various letters placed on the right of these lines will also note mediums or special conditions. I have found the following useful:

a — air (normal furnace without controlled atmosphere).

ca — compressed air.

g — gas (furnace with controlled atmosphere).

v — vacuum.

o — oil.

s — salt bath.

l — lead or other metal baths.

w — water (temperature may also be noted).

b — brine.

If the diagram seems to become too long, there is no difficulty in breaking the line showing the first heating, so that only the end near 850° C. is shown.

ROLAND MITSCHE
Professor at Montanistische Hochschule

EUROPEAN AGREEMENT ON IMPACT TEST

ZURICH, SWITZERLAND

To the Editor of METAL PROGRESS:

In the issue of METAL PROGRESS for August 1937 there appeared a letter by Federico Giolitti in which the writer mentioned an article by Mr. Menghi published in *La Metallurgia Italiana* for August 1936 about impact test bars. It is stated therein that a general agreement among European nations about "the question of the depth of notch is still under discussion after many years, and an agreement is not yet in view." Dr. Giolitti added that the profound discussions in international congresses have only resulted in ever increasing difficulties to reach an agreement on an impact standard.

On page 138 of the same issue we also find Giolitti's thought in an editorial in which the question of an agreement upon impact test bars was represented as unsolved.

As a matter of fact, at the time when Mr. Menghi was publishing his article the agreement in question was on a fair way to its realization. The earliest efforts began with the work of the former Association Internationale des Méthodes d'Essais. These deliberations, which were interrupted in 1914, were taken up again by the International Federation of National Standardizing Associations (ISA).

At a meeting of ISA Committee 17 at Düsseldorf in 1933, at which there were qualified representatives of 11 countries (Germany, Austria, Belgium, Denmark, France, the Netherlands, Italy, Poland, Sweden, Switzerland, Czechoslovakia) a majority of 10 of the 11 countries supported the preliminary adoption of the two notches, 3-mm. and 5-mm. deep, of which further tests should allow a definite selection of the standard notch. Italy was the only country which demanded adoption of the 2-mm. notch.

After that meeting numerous tests were made in several countries, notably in Germany by Mailänder, in Italy by Steccanella and Menghi, and in France by Dupuy, Mellon and Nicolau. From these researches, and after examining all the documents, a sub-committee of ISA Committee 17 met at Budapest in September 1936, and accepted the following:

"Germany proposes for an international impact test bar the dimensions 10x10 mm. and a depth of notch of 5 mm., which conforms with the French proposal. This proposal was accepted by the following 11 countries: Germany, Austria, Belgium, Denmark, Finland, France, Netherlands, Norway, Sweden, Switzerland, Czechoslovakia. Poland reserves her decision. Hungary proposes a notched depth of 5 mm. for elastic steel and one of 2 mm. for less elastic steel. Italy and Japan are in favour of a 2-mm. notch. The Assembly would have been pleased if Italy and Japan could have accepted the German proposal."

This test bar, 10x10 mm. with a depth of notch of 5 mm., was definitely adopted by ISA Committee 17 at Paris in June 1937.

It appears necessary to call the attention of American specialists studying the question of impact tests to this accomplished work which, despite the seeming lack of unanimity in the European continental countries noted in the above mentioned issue of METAL PROGRESS, indi-

cates that an agreement has been finally reached.

This is the conclusion of a long series of scientific research work and of experiments by the "Association Internationale pour l'Essai des Matériaux." In fact, this association adopted Mr. Charpy's proposition and Mr. Ehrensberger's report, first in 1909 at Copenhagen, and then again in 1912 at New York, which called for a depth of notch of 5 mm. for the 10x10 mm. bar for impact tests.

European engineers would be very pleased if their American confrères would note this important result — obtained by the International Federation of National Standardizing Associations — and if they too would adopt this standardized test bar.

H. Zollinger
Secretary
ISA Committee 17

Cause of Hair Cracks

Lafayette, Ind.

To the Editor of Metal Progress:

We recently went on a hunting expedition and bagged the specimen illustrated below at 750 diameters in some mild steel tubing.

Like the proverbial hair in the ointment, this hare was the probable cause of the specimen showing weakness in bending. We had several offers for purchase of this tubing and we learned that the proposed buyers intended to make hare springs of the material.

H. H. Lurie
Metallurgist
Ross Gear & Tool Co.

Bagged Bunny — Bad Bend

High Tensile Structural Steels Used In England

Sheffield, England

To the Editor of Metal Progress:

In the technical literature which has reached us, in England, during the last two years or so from across the "herring pond," phosphorus occupies quite a prominent position as an alloying element in high tensile structural steels. Typical analyses of some of the latter show up to 0.20% or thereabouts of this element while, in patent specifications, still higher contents are apparently visualized. Here, in this country, one hears far less about the use of high phosphorus steels, possibly because our engineers and metallurgists are more conservative and still look upon phosphorus as a dangerous impurity in steel or, perhaps, because those among them who do not regard it as being quite so bad as it is often painted are nevertheless not so optimistic as to the virtues it might confer on high strength steel even if used under controlled conditions.

Whether due to conservatism or lack of optimism, however, the development of higher tensile structural steels in this country has been colored largely by the requirements of Specification No. 548, issued by the British Standards Institution (B.S.I.), which calls for the following characteristics in steels of this type: It is stated that the steel may be made by the acid or basic openhearth or the acid bessemer steel making processes and, as regards composition, must not contain more than 0.05% each of sulphur and phosphorus. (Those familiar with the contents of B.S.I. specifications will recognize that No. 548 is by no means unique in this matter of composition!) Carbon content is also limited to 0.3% max. and the steel is required to possess the following mechanical properties:

Yield point	23 long tons per sq.in., minimum (51,500 psi.)
Tensile strength	37 to 43 tons per sq.in. (82,900 to 96,300 psi.)
Elongation	18% minimum on a gage length of 8 in.
Bend	180°, sound

The bend test is taken over a radius of 1½ times the thickness of the plate.

It may be noted that the specified range of tensile strength is rather higher than the values frequently quoted as applying to the high phosphorus structural steels used in America and, actually, could not be obtained if dependence

were placed entirely on carbon content. This is noted in the specification which further states that in order to give manufacturers the proper amount of freedom in the selection of the requisite alloying metals, limits for these are not given with the exception of copper — which may be added, at the discretion of the steelmaker, up to a maximum of 0.6%.

Steelmakers over here have produced several varieties of low alloy steels which meet these requirements and which are being used in increasing quantities where a stronger metal than ordinary mild steel is desired. The simplest type merely has the manganese content raised to 1.3 or 1.5%. Frequently, however, copper is added, in some cases about 0.3% being used while in others the copper content is raised practically to the maximum allowed in Specification No. 548.

More complex types contain chromium in addition to copper and in this case there is rather more scope for variation in composition. Generally chromium runs between about 0.5% and 1%, manganese being varied to give the requisite tensile strength.

All these varieties of steels are capable of meeting the requirements of the B.S.I. specification in the form of bars, plates, angles, and other shapes in the rolled condition. As some indication of the properties regularly obtained, the following tests on plates and sections ½ to 1 in. in thickness may be of interest:

Type of Steel	Form	Yield Point	Tensile Strength	Elongation in 8 In.
Manganese	Plate	56,000	85,100	24.0
	Angle	59,400	95,250	22.0
Manganese-copper	Plate	54,000	86,000	24.0
	Plate	54,000	85,000	26.0
	Plate	60,500	95,500	22.0
	Angle	54,200	89,600	24.0
Manganese-copper-chromium	Plate	54,900	86,200	21.5
	Plate	56,400	96,300	21.0
	Plate	59,300	95,200	19.0

Such steels as these have a workability not greatly different from that of mild steel. As regards welding, there is probably some tendency for air hardening to occur in most low alloy steels but this is reduced to a minimum in at least the manganese and manganese-copper steels, and perfectly satisfactory welds are obtained by arc welding, providing suitable electrodes are used. If riveting is preferred, the B.S.I. specification mentioned earlier calls for steel, containing not more than 0.25% carbon, which will give a tensile strength of 30 to 35 long tons per sq.in. (67,000 to 78,500 psi.) coupled with a minimum elongation of 22% on a gage length equal to eight times the diameter of the test bar.

It is not necessary to enumerate the advantages which accompany the use of these high tensile steels. In many cases, saving in weight is one of the main objects. In view of the thinner sections then used — as compared with ordinary mild steel — resistance to corrosion becomes of greater importance. For this reason, most of the high tensile structural steels actually used in this country contain copper which undoubtedly increases their resistance to atmospheric corrosion, particularly in industrial regions. It is claimed, of course, that suitable additions of phosphorus increase corrosion resistance still further, a matter of considerable interest.

The Central Research Dept. of the United Steel Companies, Ltd., has studied the matter and J. A. Jones has reported on "The Effect of Phosphorus on the Mechanical and Corrosion-Resisting Properties of Low-Carbon and of Low-Alloy Structural Steels" in the *Journal* of the Iron and Steel Institute, 1937-I, page 113. The indications are that the range of tensile strength laid down in B.S.I. specification 548 is rather too high to be met with safety in a high phosphorus steel. The latter appears to be more suitable for a tensile range of 32 to 37 tons per sq.in. (say 70,000 to 80,000 psi.) rather than 37 to 43 tons per sq.in. (say 85,000 to 95,000 psi.). Perhaps in the future the phosphorus steels may receive more consideration at the hands of British engineers than is the case at present but, for the time being, the steels most favored in this country as higher tensile structural steels are those described above.

J. H. G. Monypenny
Metallurgist
Brown, Bayley's Steel Works, Ltd.

CORRECTION

In the caption under the photograph on page 55 of the January number, an error was made in stating the precision of measurement of the Ewing extensometer. This should have been twenty millionths of an inch instead of one twenty-millionth, or 0.00002 in. instead of 0.000,000,05 in.

PERSONALS

Richard P. Stemmler has been transferred from the American Steel & Wire Co. in Cleveland to the Wire Department of the United States Steel Products Co. in New York City.

Daniel Simonds has been made manager of the steel mill of Simonds Saw and Steel Co., Lockport, N. Y.

Walther Mathesius has been appointed vice-president in charge of operations, United States Steel Corp. of Delaware. Succeeding Mr. Mathesius as manager of operations, Chicago District, Carnegie-Illinois Steel Corp., is **Walter E. Hadley**. **E. E. Moore** becomes general superintendent of the Carnegie-Illinois Gary Works, succeeding Mr. Hadley, and is replaced by **B. M. Livezey** as general superintendent of the South Works.

Appointed professor of chemistry and head of the department of chemistry at Carnegie Institute of Technology, Pittsburgh: **J. C. Warner**, formerly associate professor of metallurgy.

W. A. Olson, chairman of the Entertainment Committee, Rockford Chapter, has been appointed manager of the Cleveland office of Bridgeport Brass Co.

Transferred from staff of research laboratory, United States Steel Corp.: **Harry F. Shannon**, to Silicon Steel Division, Vandergrift Works, Carnegie-Illinois Steel Corp., as junior metallurgist on development work.

O. E. Buckius has left General Metals Corp. and is now with Great Western Electro-Chemical Co., Sacramento, Calif., doing mechanical engineering and drafting work.

William Hovaten left the employ of the Carnegie-Illinois Steel Corp., Homestead, Pa., and is now a ball mill and flotation operator at the Creede Mills, Inc., Creede, Colo.

E. S. Strang, formerly engineer of metals manufacturing at Hawthorne plant of Western Electric Co., Chicago, is now vice-president and general manager of the New Haven Copper Co., Seymour, Conn.

Transferred to Duquesne Works, Carnegie-Illinois Steel Corp., Pittsburgh, as chief metallurgist: **Philip Schane, Jr.**, formerly chief metallurgist, Youngstown district.

Vincent I. Yesulton is now an instructor in the Vocational Department of Greenfield (Mass.) High School, teaching machine shop science, mathematics and drawing.

Laboratory metallurgist with General Railway Signal Co., Rochester, N. Y.: **E. A. Basilio**, formerly metallurgist in the laboratory of General Electric Co., Pittsfield, Mass.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PERSONALS

Appointed district manager in charge of steel and tube sales in the Eastern and Southern Pennsylvania district: **W. P. White,** by Timken Roller Bearing Co. **A. R. Adelberg,** district manager in New York City, will supervise steel and tube sales in the Philadelphia as well as in the New York City district.

Roy E. Paine, secretary-treasurer of the Golden Gate Chapter, has been transferred from Oakland, Calif., to the Los Angeles works of Aluminum Co. of America, Pacific Coast Division.

Appointed secretary pro tem of the Golden Gate Chapter: **John Bermingham,** E. F. Houghton & Co. Appointed treasurer pro tem: **Frank B. Drake,** Johnson Gear and Mfg. Co., Ltd.

Gerald M. Cover has been appointed associate professor of metallurgy at Case School of Applied Science.

G. A. Ledebur has been appointed representative of the Ajax Electric Co., Inc., in the Western New York and Western Pennsylvania territory.

K. F. Finlay is now located in Painted Post, N. Y., for Ingersoll-Rand Co.

Employed as student observer at Clairton Works of Carnegie-Illinois Steel Co.: **Robert H. Bright**, formerly student at West Virginia University.

Transferred: **Porter R. Wray**, from United States Steel Corp. Research Laboratory, Kearny, N. J., to the alloy division of Carnegie-Illinois Steel Corp. in Pittsburgh.

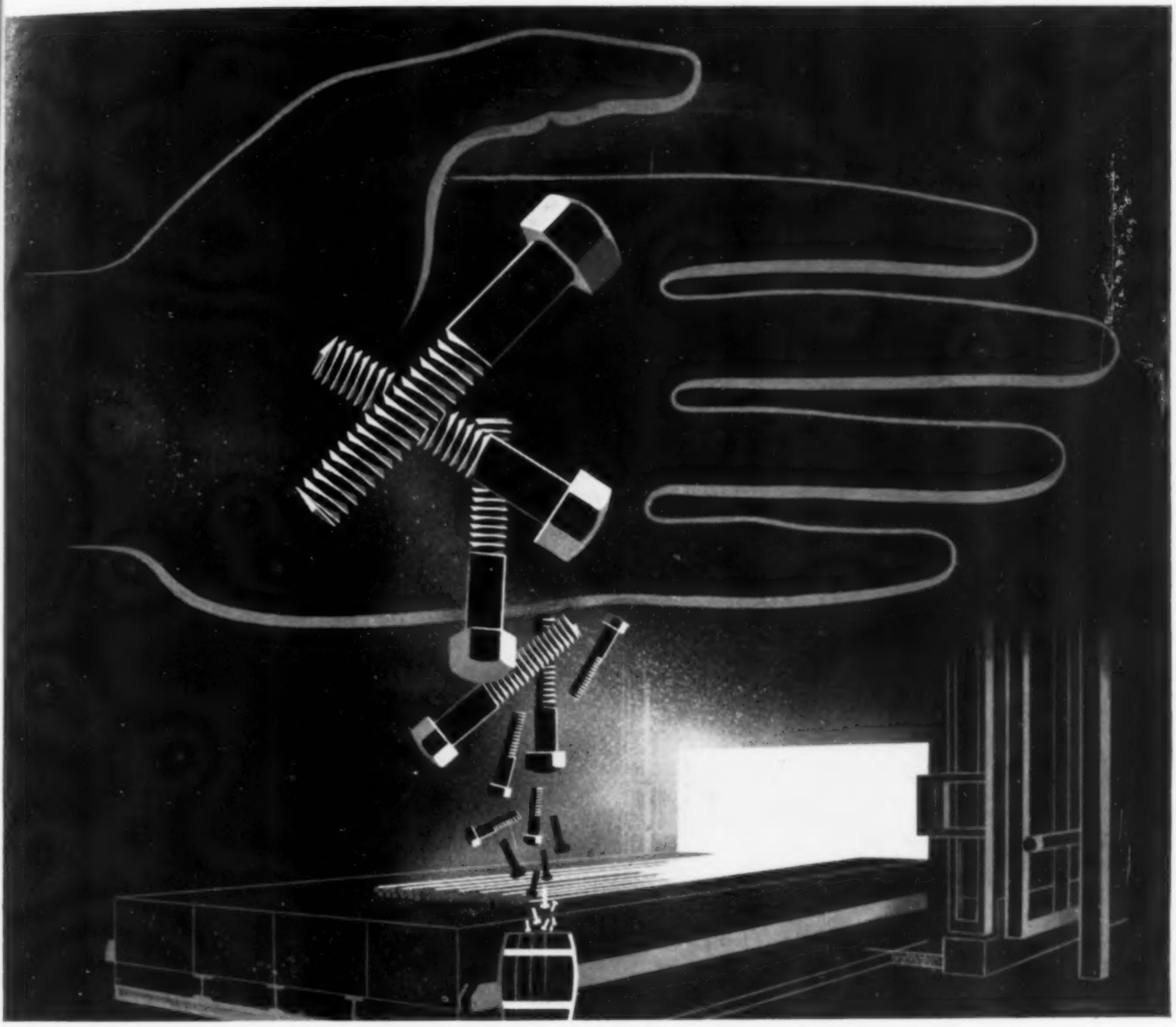
J. A. Ogilvie, formerly chief metallurgist of the Duquesne Works of Carnegie-Illinois Steel Corp., has been transferred to the Tennessee Coal, Iron & Railroad Co. in Birmingham, Ala.

Appointed by the Cambridge Wire Cloth Co.: **George B. Fletcher,** as sales engineer for the Pittsburgh territory, covering West Virginia, eastern Ohio, western Pennsylvania, and the western part of New York State.

Edward M. Voss is now representing the Philadelphia Drying Machinery Co. in western Pennsylvania, eastern Ohio and West Virginia, with headquarters at Pittsburgh.

Rolland E. Stentz has been placed in the experimental laboratory set up in Cleveland for the products development department of Republic Steel Corp.

Lawrence H. Seabright is now working in the Feeder Engineering Dept. of Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., as laboratory and materials engineer specializing in metal finishing work.



PERSONALS

W. E. Unverzagt, formerly associated with National Tube Co., McKeesport, Pa., is now doing metallurgical research at United States Steel Corp. Research Laboratory, Kearny, N. J.

William C. Meyer is at present employed by the General Cable Corp., Rome, N. Y., as a student engineer taking the training course.

K. L. Crickman is now in charge of the Indianapolis and St. Louis districts for the Carpenter Steel Co., with headquarters at Indianapolis.

Jack Salvador is now located at the Peoria, Ill., plant of R. G. Le Tourneau, Inc.

Appointed sales manager of the Smootharc Welder and Welding Electrode Division, the Harnischfeger Corp. of Milwaukee: **Abbott F. Riehle**, formerly in charge of sales for Riehle Brothers Testing Machine Division of American Machine and Metals, Inc.

Albert Reichmann has resigned as vice-president of the American Bridge Co., having reached the retirement age of 70.

Frank M. Daughety has been appointed comptroller of Peter A. Frasse & Co., Inc., New York City.

George T. Hubbell has been appointed district representative for the State of Michigan by the Mullite Refractories Co., Shelton, Conn.

Appointed manager of the Buffalo, N. Y., sales office of Worthington Pump and Machinery Corp., Harrison, N. J.: **W. A. Meiter**, succeeding **C. C. Scott**, who will devote his entire time to special work in the Buffalo district.

Promoted from assistant eastern district manager to eastern district manager: **James Boyd**, by Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., with headquarters in New York City.

Murray B. Wilson has been made manager of the New York sales district of the American Rolling Mill Co.

Carl Hildebrand, Cleveland, has been retained in an executive capacity by Sandvik Steel, Inc.

Appointed by Kropp Forge Co.: **David C. Babcock** as representative in the Michigan territory.

Wayne Z. Friend has been added to the Development and Research Staff of the International Nickel Co., Inc.

WIRE ROPE AT LOW TEMPERATURES

BY ANTON POMP AND ALFRED KRISCH

Abstract from Mitteilungen, Kaiser-Wilhelm-Institut für Eisenforschung, Vol. XIX, p. 97, 1937

HOISTING and telpherage cables are exposed to considerable variation in temperature during the course of a year. In mountainous country particularly, temperature changes are often very abrupt, and readings as low as 60 below zero may be recorded. Little is known about the properties of rope wire at these low temperatures and the authors have therefore investigated 20 types of wire to determine tensile strength, elongation, reduction of area, resistance to bending, and torsion strength in the range 70 above to 60 below zero Fahrenheit. Twelve of these were patented wires with carbon varying between 0.41 and 0.77%. Tensile strength ranged from 190,000 to 250,000 psi. at room temperature, and diameter of wire from 0.079 to 0.158 in. Three were low carbon steels with 85,000 to 91,500 psi. tensile strength, and the remaining eight wires were 0.56% carbon steel tested at various stages of drawing.

A 3-ton universal testing machine was used with a special attachment for the low temperature tests, which utilized a mixture of alcohol and carbon dioxide snow as the cooling medium in an inner container, with a circulation of air between it and the outer jacket. The test piece and specimen holder were completely immersed in the bath. The cooling medium was kept in constant circulation by evolution of carbon dioxide, so that accurate temperature readings could be taken from the bath rather than from the test piece itself.

All tests were made on bars 6.7 in. (170 mm.) between specimen holders. In the torsion test, results were calculated to a length 100 times the diameter of the wire, in a formula which gave comparable results in the bend test on wires of different diameters.

Tensile strength of all the wires tested increased uniformly as the temperature was lowered, averaging 3 to 4% higher at –20° C. (–4° F.) and about 6% higher at –50° C. (–60° F.). No relationship was *(Cont. to page 188)*

WIRE AT SUB-ZERO

(Cont. from page 182) found between carbon content and tensile strength, but tests of the same wire at different percentages of reduction showed a slightly lower increase in tensile strength with the larger number of passes. The effect of the lower temperatures on elongation and reduction of area was almost negligible.

Bend and torsion properties, on the other hand, were far less uniform and seemed to be affected to a greater extent by variations in composition and properties of the wire. They were generally lower at the lower temperatures, and many tests gave minimum values at –20° C. (–4° F.), a temperature frequently encountered in Europe. The wires with 0.03% carbon showed a slight increase in torsion strength at –50° C. (–60° F.), but with higher carbon the torsion strength was generally lower at –50° C. than at room temperature.

Effect of drawing was erratic. Torsion strength decreased considerably at –20° and –50° C. after the first three passes but remained constant at all temperatures after the fourth pass. After the fifth pass the wires showed maximum torsion strength at –20° C. (–4° F.). Only about 20% of the wires investigated showed any substantial lowering in bend and torsion properties, the detrimental effect being very slight for the others.

From these results the authors conclude that if additional stress is induced in wire rope by cooling to low temperature, with consequent contraction, it is compensated for to a certain degree by the increased tensile strength at low temperatures. A wire stretched tightly between two points contracts about 0.07% when cooled from +20 to –50° C. with a consequent increase in load of about 21,300 psi. This added load, however, induces in the wires investigated a proportionately somewhat smaller increase in tensile strength (about 6%), so that the factor of safety is lowered in spite of the higher tensile strength. In a stressed slack rope, the relationship is still unfavorable and it must be taken into consideration in calculating stresses for almost all wires at low temperatures.

Low temperature bend and torsion tests are not considered necessary for all wire which is to be woven into rope, but are recommended for applications which are likely to involve these types of stress.

WELDING OF STAINLESS

(Cont. from p. 156)

After the welding is completed, our practice has been to clean the welds thoroughly by sandblasting and then go over them with an acidified cyanide solution for evidence of iron. Any particle of iron or even a section of high iron content will produce the typical greenish blue discoloration of ferricyanide.

Chromium-iron alloys, containing 15 to 16% chromium, are among the finest materials in the stainless group, especially to resist oxidizing acids such as nitric. It was long considered non-weldable because of grain growth and resultant brittleness of the weld. We select a rod containing 1½% more chromium than the steel plate to take care of the average amount oxidized in welding. We have also found it advisable to preheat all the chromium irons slightly before welding.

Subsequent heat treatment is designed to minimize the brittleness caused by grain growth in the welds. A spheroidizing treatment is most effective. Five years ago we evolved a heat treatment basically the same as is used for the spheroidization of the high carbon and S.A.E. grades of steel and, as a result, we have been able consistently to produce welded structures of chromium iron having corrosion resistance equal to the virgin plate and at the same time are able to guarantee bend tests of 180° with radius equal to the plate thickness. Impact values are sufficient for service requirements and will run rather consistently around 10 to 12 ft-lb. Charpy.

The heat treatment is to heat slowly to a temperature of 1475 to 1575° F., maintaining at this temperature for 6 hr. The exact temperature is dependent upon the chromium content, as this governs the point at which spheroidization occurs. Then cool very slowly to about 1100° F. and then either air or furnace cool at a normal rate. Many metallurgists recommend a rapid cool from the 1100° temperature, but our records do not show that this affects the results on welded vessels.

18-8. We have built many large storage tanks for acetic acid with walls of 18-8 so thin that they would collapse during the usual high temperature heating before quenching. It was therefore necessary to develop a method of welding that would eliminate, or at least minimize, carbide precipitation. In this process, on which we have made patent application, termed "water-cooled welding process," a jet of cold water is played on the under side of the weld as it is made. This rapidly cools the deposited metal and the plate material immediately adjacent. We have successfully applied it to a large number of vessels and have found it to be entirely satisfactory, particularly on thin sections.

AUTHORS IN THIS ISSUE

Sam Hoyt, in response to an appeal for a portrait, wrote, "Its absence will not hurt the second part of my article" (on Metal Ceramics, page 157), so we dug an old one out of the morgue. It still looks very much like him, except it should show a briar pipe and a florid complexion. Dr. Hoyt taught at Minnesota before joining General Electric. At Nela Park he found time to write our favorite Metallography — even if only two of the three volumes have been printed — and at Schenectady he did a lot of work on tungsten carbide. For five or six years he has been with A. O. Smith Corp. in Milwaukee, latterly director of that firm's metallurgical research.

Duncan P. Forbes's article giving the very latest "dope" on cast iron is solidly based on many long years of experience in foundry problems. A Yale graduate in 1919, Mr. Forbes spent an additional short period of study in the laboratory of Enrique Touceda of Albany, N. Y. His subsequent experience has been entirely in the employ of Gunite Foundries Corp., Rockford, Ill. The thoroughness of his training can be judged from the list of his successive positions — metallurgist, foundry foreman, works manager and president.

This year **William M. Sheehan** celebrates the silver anniversary of his association with the Commonwealth Steel Co., predecessor of General Steel Castings Corp. He is still there, now as manager of eastern district sales with headquarters at Eddystone, Pa. A railroad man from the beginning, Mr. Sheehan gained his early experience on the Norfolk and Western and the Erie. His interests crystallizing in the mechanical details of the business, he served for a time in the engineering departments of General Electric Co., American Locomotive Co., New York Air Brake Co., and Keith Car and Mfg. Co. before going to Commonwealth. His article on page 151 reflects the active part he has taken in the development of devices of cast steel for railroad cars and locomotives.

One of the first accomplishments in the professional life of **Francis Edwin Bash**, who tells in this issue how to estimate the life of electrical heating elements (page 143), was the development of the disappearing filament type optical pyrometer. This work was done at Leeds & Northrup Co., where he went in 1916 as research engineer. (His bachelor of science from University of Washington and chemical engineering from Wisconsin were obtained in 1916 and 1919.) While at Leeds and Northrup, where he also had charge of production of electric furnaces and later was made manager of production control, he worked on the development of electric alloys for thermocouple and resistance applications, including "constantan" and "manganin." In 1923 he joined the Electrical Alloy Co. in Morristown, N. J., as manager of the technical department, and since 1928 has held the same position with the Driver-Harris Co., Harrison, N. J. His interest in life-testing of wires dates from 1924 and has borne fruit in the form of faithful service on numerous technical committees of the American Society for Testing Materials and other organizations.


Bachrach
Samuel L. Hoyt

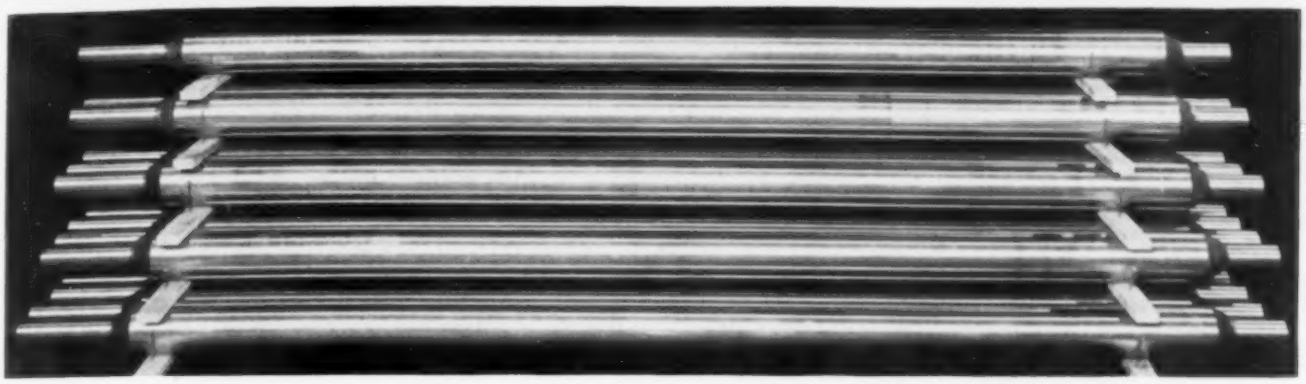

Rowland
Francis E. Bash


William M. Sheehan


Kaiden-Keystone
Duncan P. Forbes

MISCO "Centricast" Furnace Conveyor Rolls

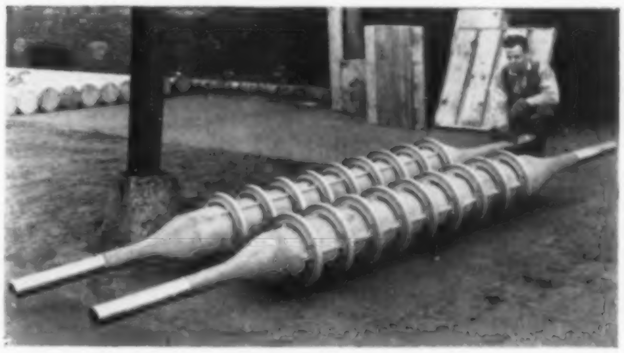
(Centrifugally Cast)



No mechanical joints are used in the manufacture of Misco "Centricast" rolls. The end castings (trunnions) are *flash welded* to the centrifugally cast tube. This construction was *originated* by Misco and more than 1200 of these rolls are now in service at temperatures up to 2050° F. Misco "Centricast" furnace conveyor rolls are sound and of uniformly fine grain structure. They combine light weight with rugged strength, low cost with long life.

"Centricast" is a Registered Trade Name

Misco "B" centrifugally cast conveyor rolls turned and ground



Misco "B" "Centricast" shafts for sheet normalizing furnace

Misco flash welder in action

OTHER MISCO "Centricast" PRODUCTS

are Carburizing and annealing boxes, Retorts, Pipe, Tubing, Sleeves, Bushings, Liners, Rolls.

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FRICTION AND LUBRICATION

(Continued from page 162)

tions and their capacities have to be determined according to their precision and surface finish with due regard to the effects of elastic bending, tilting, and imperfect alignment on the distribution of load and the geometry of the film.

Shaft bearings for internal combustion engines and big-end bearings of connecting rods can rely very little on thermodynamic theory and their design is based largely on experience. The empirical character of these methods is ascribed partly to lack of rigidity of the rubbing parts, and uncertainty of the relationship between heat dissipation and temperature rise, but more particularly to the cyclic fluctuations of the bearing load — which surprisingly prove beneficial to bearing capacity. Inertia forces predominate over combustion forces. There is little trouble encountered today which can be attributed to poor lubrication.

The most acute problem regards the choice of suitable materials. White metal is apt to crack under heavy loads. Lead bronze is expensive, needs a hard shaft, and clearances must be large (which increases the difficulty of oil control), and finally is corroded by some oils. Synthetic resin has been suggested as a bearing material, but there is no record of its being used in internal combustion engines, except experimentally. It appears to be very kind to the shaft on which it runs, but there is some doubt as to whether it can stand the high temperatures.

The important feature in big-end rod bearings lies in the cooling. The use of emulsions of water and oil is suggested instead of plain oil, since the cooling would be better and the viscosity could be controlled better, as many emulsions actually increase in viscosity as the temperature rises. Steam locks would interfere with proper distribution and circulation above 212° F.

In the research on filters, some authorities claim that oil can be used indefinitely with proper filtering, although some acid may be formed which adds to the oiliness or which can be removed by washing in a centrifuge with water. Small iron particles can be removed magnetically.

It is generally agreed that cylinder wear is caused chiefly by two factors: (1) Abrasion; (2) corrosion. There is much controversy as to which is the more important. Data were presented to show that wear is caused chiefly at the start and therefore by corrosion. Others consider it to be abrasion and therefore may be reduced by a more copious supply of oil and improved piston rings. Anti-oxidation oils seem to limit the cylinder wear perhaps by preventing corrosion.

M A G N E S I U M

(Cont. from page 147) a condensate in powder form (frost). Some 40 to 50 volumes of hydrogen are injected per volume of magnesium vapor. The hydrogen should be rather pure, particularly low in carbon monoxide, and free from water vapor and carbon dioxide. Uncondensed vapors are cleaned by dust filters, purified of carbon oxides, and the hydrogen is thus regenerated almost completely.

Magnesium powder is removed continuously by screw conveyor. It is quite explosive in air, but is easily preserved by coating the particles with oil. This is a regular procedure before briquetting the powder and sending it to a redistillation furnace.

The powder carries 60 to 70% of its weight in metallic magnesium, and 15 to 22% magnesium oxide. The remainder includes impurities from the magnesite and the reducing agent which had been volatilized at the high temperature of the reduction furnace, besides some carbon and dust carried over. A recovery of 80 to 90% of the magnesium content of the ore in the form of powder is attainable.

Redistillation is done in a closed furnace, tight against a vacuum of 20 mm. mercury. Heating to 1700° C. is by internally placed electrical resistors. The briquetted powder is introduced through hydrogen-locked hoppers. Distillation takes place under the high vacuum, the vapors passing to a condenser. Here the vapor coalesces into globules, varying in size from fine shot up to spheres ½ in. diameter. They drop into an oil-filled hopper, from which they are elevated to a barometric leg, and from the open bottom to containers. The oil is screened out and returned to the hopper. The non-volatile residue is mechanically removed from the redistillation furnace through traps and discarded or returned to the raw material stock. The operation of this furnace is practically continuous; recovery is about 98% of the metallic content of the briquettes.

The metal produced by this distillation process is of remarkable purity, for remelting by electric heat introduces no new impurity.